ISSN : 2708-8979

Hornbill Natural History *and* Conservation

Hornbill Specialist Group | September 2024

Volume 5

The IUCN SSC HSG is hosted by:

Mandai NATURE

Co-chairs: Aparajita Datta and Lucy Kemp

HNHC Design
Janhavi Rajan, Nature Conservation Foundation, India

Cover Photograph
Great Hornbill *Buceros bicornis* Photo: © K. Phanakorn

nature conservation foundation

MABULA GROUND HORNBILL PROJECT

CONTENTS

RESEARCH ARTICLES

NOTES FROM THE FIELD

Non-breeding season population density of hornbills in the core area of Khao Yai National Park, Thailand

Naphatsorn Monchaithanaphat[1], Yongyut Trisurat[2,*], and Vijak Chimchome[2]

[1] *Forest Resource and Environmental Administration, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand*

[2] *Department of Forest Biology, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand*

***Corresponding author:** Yongyut Trisurat (fforyyt@ku.ac.th)*

Abstract

*Hornbills are recognized as environmental indicators and are the focus of awareness-raising and tourism activities, but their populations are declining due to habitat degradation and poaching in Thailand. The objectives of this study were to estimate the population densities of four hornbill species found in Khao Yai National Park, Thailand, namely Oriental Pied Hornbill (*Anthracoceros albirostris*), Great Hornbill (*Buceros bicornis*), Wreathed Hornbill (*Rhyticeros undulatus*), and Austen's Brown Hornbill (*Anorrhinus austeni*). In the core area of the national park, covering 144 km^2 (12 km × 12 km), we surveyed the hornbills along 10 line transects of approximately 1.5 km length along nature trails, roads, and patrol routes in the non-breeding season from June 2022 to December 2022. Distance sampling density estimation using the DISTANCE 7.5 program showed that the population density of Oriental Pied Hornbill, Great Hornbill, and Wreathed Hornbill were 10.48 (n = 47), 2.41 (n = 26), and 2.60 (n = 29) individuals/km^2, respectively. The densities of the first two species were lower than in an earlier study conducted in Khao Yai and in Huai Kha Khaeng Wildlife Sanctuaries, possibly due to the habitat changes and seasonal movements, respectively. Austen's Brown Hornbill was not detected during the survey period. The results can serve as a baseline for long-term monitoring of hornbill populations, help evaluate the management effectiveness and guide tourism activities in Khao Yai National Park, a portion of the Dong Phayayen – Khao Yai Forest Complex Natural World Heritage Site.*

Keywords: hornbills, population, density estimation, Khao Yai National Park

Introduction

Hornbills belonging to the Family Bucerotidae are medium- to large-sized, large-billed, long-tailed birds of tropical forests, savannas, and grasslands. Sixty-three hornbill species are distributed widely through the tropical regions of Africa and Asia (IUCN, 2024). Most hornbills live in relatively intact forests, and nest in cavities in large trees, while some species, such as the Southern Ground-Hornbill (*Bucorvus leadbeateri*) in Africa, occur in grassland and open woodland (Combrink *et al*., 2020). Of the thirteen species of hornbills recorded in Thailand (Poonswad *et al*., 2013), populations of twelve species are decreasing (IUCN, 2024) chiefly due to forest fragmentation and habitat loss. Hornbills are recognized as keystone species

noted for their role as seed dispersers in tropical forests, due to which they are commonly referred to as forest farmers. Nevertheless, 50% of hornbill species are vulnerable to terrestrial hunting and trapping, followed by small-holder farming and effects of logging. Based on a review of studies, Asian hornbills are known to disperse seeds of 748 plant species in tropical forests, as recorded in data on 29 different hornbill species in 98 publications from 8 countries, particularly Thailand (Kitamura, 2011; Naniwadekar and Datta, 2013). Therefore, they are recognized as ecological indicators of the integrity of environmental changes and as species that perform crucial ecosystem functions. In addition, hornbills have distinctive features such as large bills, casque and peculiar breeding habits making them attractive and charismatic species suitable for awareness raising and tourism activities.

Thailand's forest cover in 2023 was 31.47% of the total country area, following a decrease of over 50,800 ha from the previous year (Forest Land Management Office, 2023). Besides habitat loss and fragmentation, the destruction of primary forest is also diminishing hornbill habitat and reducing availability of potential breeding sites and food resources. Moreover, nest trees losses and poor cavity condition can be a natural threat to hornbill populations and breeding. Repairing cavities before the breeding season has therefore been emphasized as a technique by the Thailand Hornbill Project team (THP team) to increase the breeding opportunities. In Khao Yai National Park, Thailand, populations of hornbills, especially Great Hornbills (*Buceros bicornis*), would have likely decreased without cavity monitoring and management (Poonswad *et al.*, 2013). Among other species, Rufous-necked Hornbill (*Aceros nipalensis*) is absent from Mae-Ping-Omkoi and Doi Phukha-Mae Yom Complexes in Thailand because of hunting and forest encroachment, while the Tickell's Brown Hornbill (*Anorrhinus tickelli*) and Great Hornbill persist at low abundance at Om Koi but have disappeared from Mar Tuen, Thailand, because of prolonged fragmentation (Pattanavibool and Dearden, 2004; Trisurat *et al.*, 2013). Globally, the IUCN has designated three species of hornbills as Critically Endangered, five as Endangered, seventeen as Vulnerable, and other species at lower risk (IUCN, 2024). In addition, most hornbill species in Thailand have been classified as endangered or critically endangered by the Thailand Red List (ONEP, 2017).

There are 18 forest complexes (Fig. 1a) and 445 units of protected area covering 108,115 km^2 or approximately 21% of the land area in Thailand (DNP, 2021, 2022). A recent study reported that hornbills are distributed in 12 forest complexes in Thailand, with the total extent of hornbill habitats spanning 9.3% of the country's land area (Fig. 1b, Trisurat *et al.*, 2013). The nationwide assessment indicated that Thailand's hornbills are mainly concentrated in 5 hornbill hotspots among the total 18 protected area complexes, namely Western Forest complex (WEFCOM), Dong Phayayen – Khao Yai, Khlong Saeng – Khao Sok, Khao Luang, and Hala Bala. These areas have high species richness, conservation status and potentially suitable habitat size criteria more than other complexes. The WEFCOM is the largest surviving forest in Thailand where five hornbill species are recognized. Despite the complex's high biodiversity, human disturbances, illegal logging, agricultural practices, and wildlife poaching occur in this area. (Emphandhu and Kalyawongsa, 2006; Trisurat *et al.*, 2013). Dong Phayayen – Khao Yai, was isolated from other complexes so it plays a role as a source of hornbills in the north-east besides being important for Austen's Brown Hornbill *Anorrhinus austeni* (Trisurat *et al.*, 2013). Six hornbill species were

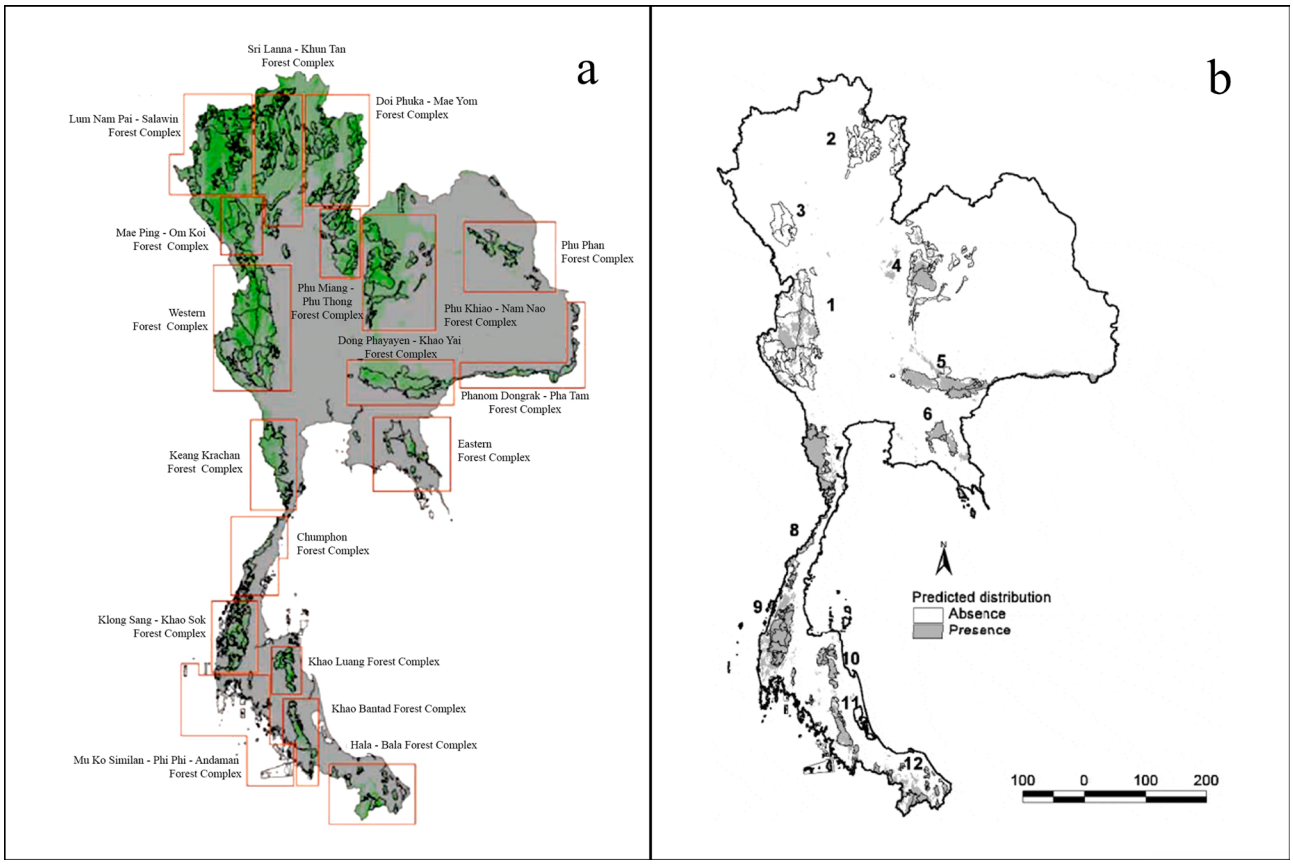

Fig. 1. Map of Forest Complexes in Thailand (a) (DNP, 2021) and (b) the predicted distribution map of hornbills (Trisurat *et al*., 2013).

found in Khlong Saeng-Khao Sok complex (Trisurat *et al*., 2013). Human disturbance and forest fragmentation affected the Khao Luang forest; however the Black Hornbill (*Anthracoceros malayanus*) occurs here (Round *et al*., 2006; Trisurat *et al*., 2013). Although Hala Bala was subject to logging during 1987 – 1992, it is home to nine of the thirteen species of hornbills, especially Rhinoceros Hornbill (*Buceros rhinoceros*) and Wrinkled Hornbill (*Rhabdotorrhinus corrugatus*) only found in this habitat (Gale and Thongaree, 2006; Trisurat *et al*., 2013).

Nevertheless, areas outside protected areas can offer potentially suitable habitats for some hornbill species. Thus, increasing connectivity of suitable habitats not only in forest complexes, but also outside, can help in maintaining hornbill populations. Furthermore, hunting is a big threat to hornbills since their large size and loud calls and sound make them easy and preferred targets of hunters (Poonswad *et al*., 2013).

Besides species distribution, species abundance or population density is an essential parameter to determine species status and response to changes in forests and other environmental factors (Balvanera *et al*., 2022; Brodie *et al*., 2013). In Thailand, some hornbill species are classified as "a protected wild animal" while others are classified as "a conserved wild animal" and studies on hornbill populations are critical for conservation management (Royal Thai Government Gazette, 2019). However, hornbill population estimations have been done unsystematically in selected protected areas in Thailand (Round *et al*., 2005;

BirdLife International, 2023a. 2023b; Gale and Thongaree, 2006; Johnburom *et al.*, 2010). As mentioned above, Khao Yai is the core area of WEFCOM and is recognized as a hotspot for biodiversity conservation. Understanding temporal variation in densities provides crucial information for formulating effective conservation strategies based on species-specific abundance patterns and population trends. To address this knowledge gap and obtain a baseline for use in future monitoring, the objective of this study was to estimate the population density of four hornbill species in the core area of Khao Yai National Park during the non-breeding season.

Methods

Study Area

The research was carried out at Khao Yai National Park in central and northern Thailand. Khao Yai National Park was established as the first national park in Thailand in 1962. Khao Yai National Park is a part of the Dong Phayayen – Khao Yai Forest Complex (DPKY), which comprises five almost contiguous Protected Areas: Khao Yai National Park, Thap Lan National Park, Pang Sida National Park, Ta Phraya National Park, and Dong Yai Wildlife Sanctuary. This protected forest complex was inscribed as a UNESCO natural world heritage site in 2005. Meanwhile, Khao Yai was designated an Asian Heritage Park, an important bird area (IBA, BirdLife International, 2023), and a key biodiversity area or KBA (Tordoff *et al.*, 2012). It was the first study site of the Thailand Hornbill Project initiated in 1978 (Poonswad *et al.*, 2013). The Park covers approximately 2,168 km^2 and encompasses a heterogeneous landscape across altitudes ranging from 101 m above sea level to 1,351 m at the Khao Lam peak. The average annual rainfall is 2,250 mm with the rainy season from May to October and highest rainfall in September. The average temperature is 22°C during the day and 9–10°C during the night. Khao Yai remains covered by evergreen forest (78% of the area) and mixed deciduous forest (10%), with much of it tall, good quality primary forest, besides remnant grassland and secondary growth (Temchai *et al.*, 2014).

Khao Yai National Park provides habitats for more than 800 faunal species, including 112 species of mammals, 400 species of birds, and 200 species of reptiles and amphibians. It is internationally important for the conservation of globally threatened and endangered species such as elephants (*Elephas maximus*), leopard cats (*Prionailurus bengalensis*), banteng (*Bos javanicus*), gibbons (*Hylobates lar* and *Hylobates pileatus*) and hornbills (UNESCO).

Based on long-term monitoring data, Khao Yai provides habitats for 4 out of 13 hornbills in Thailand including Oriental Pied Hornbill (PH) *Anthracoceros albirostris*, Great Hornbill (GH), Wreathed Hornbill (WH) *Rhyticeros undulatus* and Austen's Brown Hornbill (BH) (Poonswad *et al.*, 2013). Previous hornbill studies in Khao Yai also included home ranges of male Great, Brown and Wreathed Hornbills (Poonswad and Tsuji, 1994) and the nest site characteristics of four sympatric hornbill species (Poonswad, 2008).

The density of four hornbills including Oriental pied Hornbill (PH), Great Hornbill (GH), Wreathed Hornbill (WH), and Austen's Brown Hornbill (BH) at Mo Singto forest dynamics plot, which is dominated by evergreen forest surrounded by forest edge and secondary growth, was estimated at 0.57, 0.04, 0.13 and 0.02 individuals/ha, respectively (Round *et al.*, 2005). Since then, there has been no population estimation in Khao Yai National Park.

Khao Yai National Park is the highest visited national park in Thailand with around 1.4 million visitors per year (DNP, 2022). The main human activities in the park are hiking, wildlife watching, visiting waterfalls, and camping. Moreover, Khao Yai is the one of the best places for bird watching in Thailand (Khao Yai National Park, n.d.). Promoting ecotourism, besides economically benefiting the park, can also help in conserving and raising awareness on hornbills if proper birdwatching etiquette, observer behavior and environmental sensitivity are fostered. Ecotourism during wildlife watching can supplement patrolling of the park (Koid *et al.*, 2021). Ecotourism can potentially have positive impacts for hornbill conservation, alongside other management efforts such as cavity monitoring and repairing, and protection from human disturbance and logging in the protected area and surrounding buffer zone. Presently, Khao Yai lacks up-to-date information on hornbill population density and trends to evaluate the management effectiveness and to guide tourism activities in the park.

Survey method

The intensive study site for hornbill density estimation was located in the core area of Khao Yai, covering 144 km^2, around the park headquarters. Habitat types include moist evergreen forest (44%), dry evergreen forest (39%), mixed deciduous forest (11%), secondary growth (4%), grassland and others (3%) (Temchai *et al.*, 2014). This area has many hornbill nests (Thailand Hornbill Research Foundation, 2022) and there are many natural trails providing easy access. Elevations range from 515 m to 880 m above sea level.

Field surveys were conducted using line transect sampling between June 2022 to December 2022 mostly in the non-breeding season. Transects were surveyed from 06:00 to 11:00 h and from 14:00 to 17:00 h to record hornbills, avoiding days with heavy rain or high winds (Mynott *et al.*, 2021). The 144 km^2 (12 km x 12 km) study area was surveyed using 10 transect lines, covering natural trails, roads, and patrol routes. The transect lines were approximately 1.5 km long and spaced at least a kilometer apart to prevent duplicate counts. Each transect was walked 7 times to cover at total of 105 km (1.5 km x 10 transect x 7 revisits). There was 30 days gap between revisits to the same lines. We recorded all direct hornbill detections, both visual and aural.

For each hornbill detection, we recorded the species, number of individuals, and sex. Angles between the observation and the transect line were measured using a compass, and the distances between the observer and the bird were measured using rangefinders (Nikon Coolshot 20 GII). Besides weather conditions, we also recorded hornbill behavior such as singing, perching, and flying, as well as other activities such as eating and resting. The total survey distance was 105 km (1.5 km × 10 survey lines x 7 replications). For flying hornbills detected, we measured distance between the observer and a tree located on the same vertical plane. Locations of hornbill occurrences were recorded in UTM using AlpineQuest Off-Road Explorer 2.3.3d mobile phone application.

Data Analysis

As hornbills are large, conspicuous and mobile species, we used line transect surveys and distance sampling methods to estimate population densities (Gregory *et al.*, 2004). The data collected were analyzed using the DISTANCE 7.5 Windows computer program (Thomas *et al.*, 2010). Hornbill cluster sizes were estimated from the data on number of individuals in each detection. Density estimation was based on selection of the detection function that best fit the

data from among half-normal, hazard-rate, and uniform models with cosine adjustment terms. Model selection procedure followed Buckland *et al.*,(1993), which included: (1) selecting the model with the lowest AIC (Akaike's information criterion), as the best and parsimonious fit; (2) choosing the lowest percentage coefficient of variation (%CV) as indicative of the precision of the estimate, and (3) based on the Chi-square Goodness-of-fit test (P>0.05) indicative of model fit. Along with that we used 150 m and 160 m right truncation for estimation of densities of PH and GH, respectively. These truncation distances provided suitable visual detections of these two species and the lowest AIC. Likewise, we used 250 m right truncation for WH because we often detected it at longer distances than PH and GH. In addition, we estimated densities considering two options: (1) only visual detections, and (2) combined visual and auditory detections, then evaluated the performance of both options.

We created the distribution map of hornbills by overlaying hornbill observer positions and environmental variables. The observation positions were derived from the angles between the observation and the transect line and the distances between the observer and the bird. We used QGIS software (version 3.22.7) to derive relevant environmental data, including forest type, digital elevation model (DEM), distance to stream, distance to road, distance to building, and distance to ranger station (Temchai *et al.*, 2014) as indicative descriptors of habitat preferences of hornbills in the landscape.

Results

Hornbill detection, cluster size and encounter rate

During the 7-month survey, we encountered 538

Table 1. The number of hornbills found in the core area of Khao Yai National Park between June 2022 and December 2022.

Species	Number of detections						Total detections	Total individuals sighted
	During transect			Supplementary observations				
	Visual	Auditory	Total	Visual	Auditory	Total		
PH	54	45	99	19	8	27	126	173
GH	38	52	90	12	11	23	113	112
WH	37	13	50	26	1	27	77	253
BH	-	-	-	-	1	1	1	-
Total	129	110	239	57	21	78	317	538

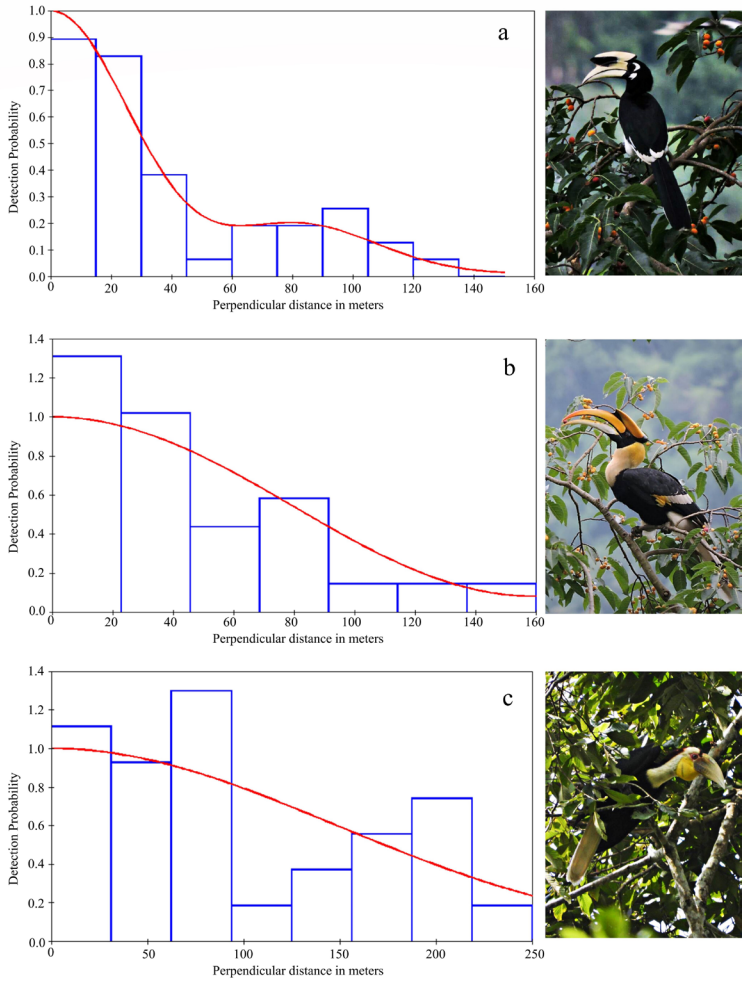

Fig. 2. Detection Probability Plots of three hornbill species in line transect surveys in the core area of Khao Yai National Park between June 2022 and December 2022: (a) Oriental Pied Hornbill; (b) Great Hornbill; (c) Wreathed Hornbill. (Photos: K. Phanakorn)

individuals of four hornbill species both along the transects and outside the transects in supplementary observations (Table 1). The numbers of WH contributed about 47% of the total individuals. During the survey period, Austen's Brown Hornbill was not detected and only one auditory detection was recorded. Therefore, it was excluded for density estimation.

Model fit (using AIC, %CV, and Chi-square Goodness of fit test) was assessed separately for: (1) only visual detections, and (2) combined visual and auditory detections. As the model results showed that visual detection data of three hornbill species provided better performance than the combined visual and auditory detections, it was used to calculate cluster sizes, encounter rates, and densities. Details of best-fit models and fitted detection functions are presented in Table 2 and Fig. 2.

Based on the visual detections of hornbills along transect lines, PH, GH and WH had mean cluster size in individuals/cluster (and encounter rates in individuals/km) of 2.33 (0.51), 2.24 (0.36), and 4.43 (0.35), respectively (Table 3).

Population density of hornbills

Based on the selected models and parameters

Table 2. Details of selected models for density estimation of hornbills in the core area of Khao Yai National Park between June 2022 and December 2022.

Species	Detection	Key function + Series expansion	Right truncation (m)	AIC	GOF χ^2 p
PH	Visual	Half-normal+cosine	150	438.87	0.56
GH	Visual	Uniform + cosine	160	253.35	0.55
WH	Visual	Half-normal + cosine	250	317.99	0.45

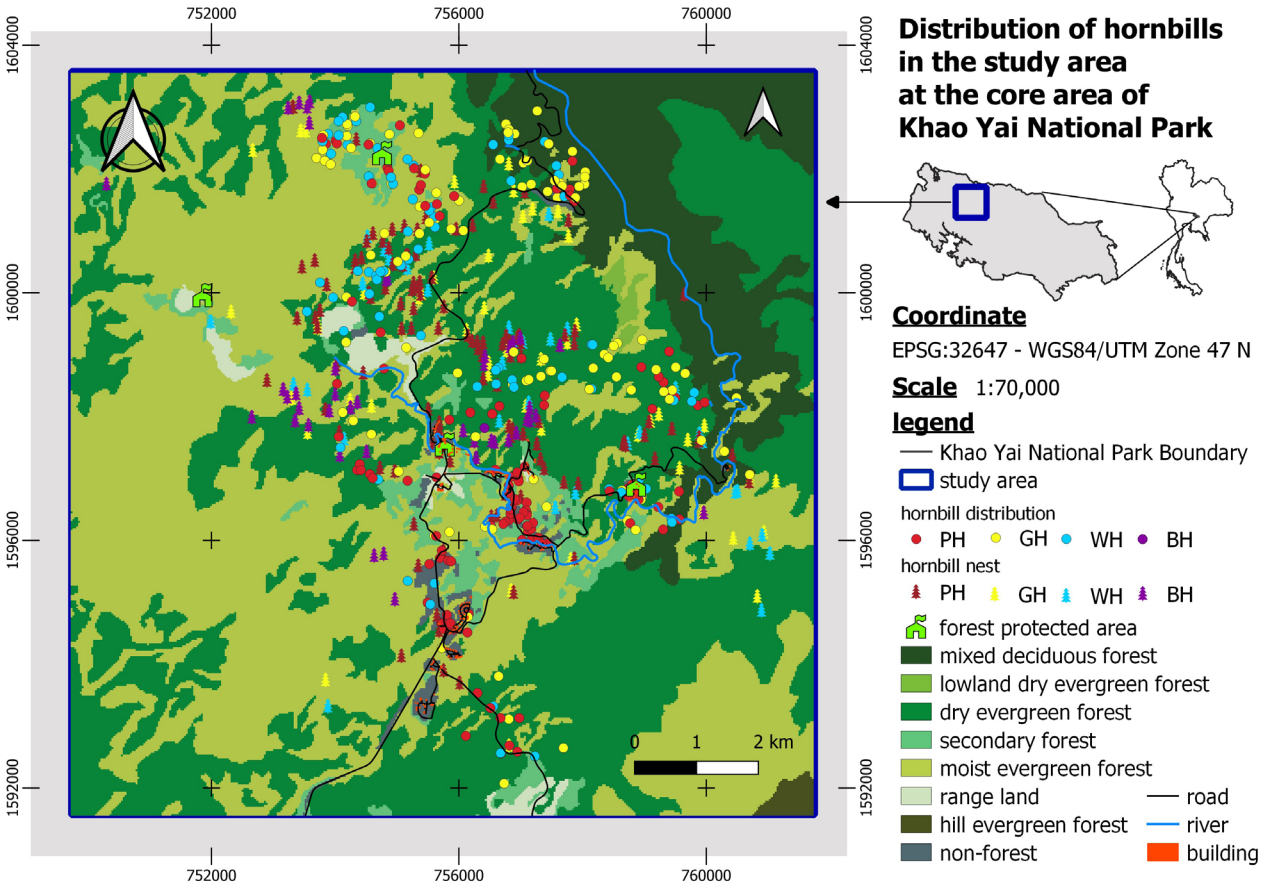

Fig. 3. Distribution map of four hornbill species with environmental layers in the core area of Khao Yai National Park.

Table 3. The mean cluster size and the encounter rate of hornbills in the core area of Khao Yai National Park between June 2022 and December 2022.

Species	Detection	Number of clusters (n)	Mean cluster size	Standard error	Encounter rate (individuals/km)
PH	Visual	54	2.33	0.17	0.51
GH	Visual	38	2.24	0.29	0.36
WH	Visual	37	4.43	0.96	0.35

Table 4. The estimated densities of hornbills in the core area of Khao Yai National Park between June 2022 and December 2022.

Species	DS	n	Density (individuals/km²)				
			D	SE±	%CV	95% CI	
						Lower	Upper
Oriental pied Hornbill (PH)	4.98	47	10.48	3.22	30.72	5.62	19.52
Great Hornbill (GH)	1.43	26	2.41	0.83	34.66	1.16	4.98
Wreathed Hornbill (WH)	0.82	29	2.60	0.87	33.31	1.33	5.12

Abbreviations: DS: density of clusters (clusters/km²); n: number of hornbill detections/clusters; D: density (individuals/km²); SE±: standard error; %CV: % coefficient of variation; 95% CI: 95% Confidence Interval

(Tables 2 and 3) we estimate PH, GH, and WH cluster densities at 4.98, 1.43, and 0.82 cluster/km², respectively (Table 4). The corresponding PH, GH, and WH densities were 10.48, 2.41, and 2.60 individuals/km², respectively. In the DISTANCE models, about 13%, 31% and 26% of visual detections for PH, GH and WH, respectively, were discarded for the analysis after right truncation.

Environmental variables in study area

The results of GIS overlay and field observations indicated that moist evergreen forest was the most frequent habitat of occurrence for all

hornbills (43.5%), followed by dry evergreen forest (39.0%), mixed deciduous forest (10.8%) and others 6.7% (Fig. 3).

Discussion

Khao Yai National Park located in the WEFCOM is recognized as a hornbill hotspot in Thailand (Trisurat *et al.*, 2013). The park provides habitats for 4 out of 13 hornbill species, namely Oriental Pied Hornbill (PH), Great Hornbill (GH), Wreathed Hornbill (WH), and Austen's Brown Hornbill (BH) (Poonswad *et al.*, 2013). In addition, Khao Yai is one of three research areas for long-term monitoring of hornbill populations and nesting (Thailand Hornbill Research Foundation, 2022). In addition, hornbills are flagship species for ecotourism in the park (Koid *et al.*, 2021). Up-to-date information on hornbill population and their distribution can therefore serve as a baseline for long-term monitoring of hornbill populations and help evaluate the management effectiveness, besides helping guide tourism activities in Khao Yai National Park.

Population density was not estimated for Austen's Brown Hornbill due to inadequate detections. The number of visual detections for PH was heighest (Table 3) likely due to PH being the most adaptable hornbill, listed as Least Concern (LC) status at global and national levels (BirdLife International, 2020a; ONEP, 2017). With their small size and broader habitat preference, they are more frequently detected (BirdLife International, 2023a). In contrast, the GH is generally found in evergreen forests and is more sensitive to human proximity (BirdLife International, 2023b). This may account for the less frequent detections of GH than PH (Hornbill Specialist Group, n.d.). The WH also normally avoids disturbed habitats and proximity to humans and despite their wide-ranging habits are more difficult to detect compared to PH and GH. Nevertheless, WH has the highest number of individuals (253 individuals; Table 1) and a higher encounter rate possibly due to larger flock sizes (maximum in a fruiting tree was up to 30).
Round *et al.*,(2005) found 57 individuals/km² of PH in a biodiversity research plot in Mo Singto at Khao Yai National Park, which is almost 5 times higher than this study (10.48 individuals/km²). Similarly, the average population density of PH in the entire Khao Yai National Park during 2004-2008 was 21 individual/km² (BirdLife International, 2023a). In addition, the density of the Oriental Pied hornbill in the Pakke Tiger Reserve in Arunachal Pradesh, India, affected by human disturbance was 19 individuals/km² (Dasgupta and Hilaluddin, 2012).

The previous studies at Khao Yai were conducted when Mo Singto covered a variety of forest types such as deciduous forest, secondary forest, grassland, and open areas. Such heterogeneous landscapes are preferred by PH (Hornbill Specialist Group, n.d.; BirdLife International, 2023a). During the last two decades, the open woodlands have been transformed to mature evergreen forests and only a few patches of secondary forest remain (Temchai *et al.*, 2014). Round *et al.*,(2005) combined line transects and circular plots to survey the birds only in morning, whereas visual detections in the morning comprised 66% of the total detections in the present survey. In addition, mist-nets and playback tapes were used to attract birds to the net in the earlier study (Round *et al.*, 2005). Therefore, the lower PH density noted during the present study may be due to both habitat changes and differences in survey times and methods.

The IUCN Red List classifies the GH as a Vulnerable species (VU) (BirdLife International, 2020b), while it is Near Threatened in Thailand

(ONEP, 2017). GH density in the present study (2.41 individuals/km²) was generally lower than other areas in Thailand and in the region, except lowland forests in Hala-Bala. The Round *et al*. (2005) estimate for GH in Mo Singto was 4 individuals/km² reflecting differences in survey methods and survey time as mentioned above. The density of the GH at Huai Kha Khaeng Wildlife Sanctuary was 5.28 individuals/km², which was higher than in this and the previous studies because Huai Kha Khaeng witnesses seasonal movements of GH and WH and has preferred feeding sites during the non-breeding season (Johnburom *et al*., 2010). Meanwhile, the density of GH in Namdapha Tiger Reserve in Arunachal Pradesh, and in Pakke Tiger Reserve in India was 3.9 individual/km² (Naniwadekar and Datta, 2013) and 3.8 individuals/km², respectively (BirdLife International, 2023b). The differences may be due to tourism activities in the Indian reserves being limited compared to Khao Yai. In addition, the GH prefers dense old growth unlogged forests. Some transects of our study cover grassland and forest edge, while the entire study in India were in large stretches of rainforests. Gale and Thongaree (2006) found 0.124 individuals/km² in Hala-Bala Wildlife Sanctuary on the Thai–Malaysia border where 9 out of Thailand's 13 hornbill species occur. Range overlap and food competition among these 9 species, especially with Rhinoceros Hornbill, may cause the lower density of GH in Hala Bala.

The WH is classified as a Vulnerable species (VU) at the global level (BirdLife International, 2018b) and as Near Threatened in Thailand (ONEP, 2017). Our study indicated the density of the WH was 2.6 individuals/km², which was slightly greater than the previous study of 2 individuals/km² (Round *et al*., 2005), but substantially greater than the Bala Forest (0.69 individuals/km²; Gale and Thongaree, 2006). This is possibly due to the Bala Forest being degraded from logging during 1987 – 1992 and becoming less suitable for WH (Trisurat *et al*., 2013). Moreover, a lower density may have been recorded as the survey was conducted in the breeding season (Naniwadekar and Datta, 2013; Poonswad and Tsuji, 1994).

In contrast, the density of the WH found in Mount Ungaran, Central Java, Malaysia (Rahayuningsih and Nugroho, 2013) and in Namdapha Tiger Reserve, Arunachal Pradesh, India were 14.60 individuals/km² (Rahayuningsih and Nugroho, 2013), and 16.1 individuals/km² (Naniwadekar and Datta, 2013), respectively. Potential reasons for differences between this and other areas include the composition of habitat types and survey methods. WH inhabits closed forest, both evergreen and deciduous, from the lowlands to the lower montane forest. About 83% of the study area are dense forests, while the reaming areas are degraded forest and grassland, while the other areas are almost entirely closed forests. This assumption is relevant to the visual detections of this study. More than 95% of total visual detections of WH and GH were found in dense moist and dry evergreen forests, but the statistical influence of these factors requires further investigation.

Evergreen forests are recognized as suitable habitats for the four hornbill species, which provide abundance of fruits and nutrient resources. There are 139 ripe fruit species, from 76 genera and 36 plant families found in the diet of hornbills (Poonswad, 2010). Additionally, the PH was detected in closed forests near road and stream because PH prefers forest edges and open woodlands whereas GH and WH were found in the core areas of primary evergreen and deciduous forests. In addition, we found that more than 90% of hornbill occurrences were at elevations above 700 m. This

is different from Namdapha Tiger Reserve, India, where low densities of Great and the Austen's Brown hornbills are noted in higher elevations (Naniwadekar and Datta, 2013). In Khao Yai, lower elevations (515 – 700 m) have been converted for cultivation before the park establishment and are now categorized as secondary growth and grassland (Temchai *et al.*, 2014).

Khao Yai National Park provides habitats for more than 400 species of birds (UNESCO) and at least 159 bird species have been recorded in the Mo Singto plot (Round *et al.*, 2005) inside the study area. In addition, birdwatching especially for hornbills is one of the main visitor activities in the park. Visitors can participate and get involved in sharing and contributing hornbill data through citizen science. The data reported by visitors can supplement long-term monitoring of hornbill populations implemented by the Thailand Hornbill Research Foundation (2022). Eventually, the combined data will increase scientific knowledge to evaluate the management effectiveness of Khao Yai National Park as a portion of the Dong Phayayen – Khao Yai Forest Complex Natural World Heritage Site. In addition, density estimation in the breeding season is highly recommended to understand spatial-temporal variation in densities and for providing crucial information for formulating effective conservation strategies.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

We are very grateful to the Thailand Hornbill Research Foundation, the Faculty of Science, Mahidol University, Khao Yai National Park and National Park research center, Nakhon Ratchasima province, Thailand.

Competing Interests Statement

Authors have no competing interests to declare.

References

Balvanera P, Brauman KA, *et al*. 2022. Essential ecosystem service variables for monitoring progress towards sustainability. *Current Opinion in Environmental Sustainability* 54: 101152.

BirdLife International. 2018b. *Rhyticeros undulatus*. *The IUCN Red List of Threatened Species* 2018. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22682528A132400385.en

BirdLife International. 2020a. *Anthracoceros albirostris. The IUCN Red List of Threatened Species 2020*. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T22682437A184925767.en

BirdLife International. 2020b. *Buceros bicornis*. *The IUCN Red List of Threatened Species 2020*. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T22682453A184603863.en.

BirdLife International. 2023. Important Bird Area factsheet: Khao Yai. http://datazone.birdlife.org/site/factsheet/khao-yai-iba-thailand

BirdLife International. 2023a. Species factsheet: *Anthracoceros albirostris*. http://www.birdlife.org

BirdLife International. 2023b. Species factsheet: *Buceros bicornis*. http://www.birdlife.org.

Brodie JF, Brockelman WY, *et al*. 2013. Complexities of linking defaunation to tree community dynamics: case studies from national parks in Thailand. *Natural History Bulletin of Siam Society* 59: 77–90.

Buckland S, Anderson D, *et al*.1993. *Distance Sampling: Estimating Abundance of Biological Populations*. Chapman and Hall, London.

Combrink L, Combrink HJ, Botha AJ, Downs CT.. 2020. Habitat preferences of Southern Ground-hornbills in the Kruger National Park: implications for future conservation measures. *Scientific Reports* 10: 16195. https://doi.org/10.1038/s41598-020-73236-4

Dasgupta S and Hilaluddin. 2012. Differential effects of hunting on populations of hornbills and imperial pigeons in the rainforests of the Eastern Indian Himalaya, Wildlife Trust of India, Pakke Tiger Reserve, Seijusa, East Kameng District, Arunachal Pradesh. *Indian Forester* 138: 902-909.

DNP (Department of National Parks, Wildlife and Plant Conservation). 2021. *Master Plan of Administration of Wildlife Conservation, Wildlife Sanctuary and Non-hunting area*. Ministry of Natural Resources and Environment, Bangkok.

DNP (Department of National Park, Wildlife and Plant Conservation). 2022. *Statistic Data of National Park, Wildlife and Plant Conservation 2022*. Ministry of Natural Resources and Environment, Bangkok, Thailand.

Emphandhu D and Kalyawongsa S. 2006. Human Dimensions in Thailand Western Forest Complex: Challenges and Opportunities. Annual research report 2006 Forest Resource and Development Office: 31-43.

Forest Land Management Office. 2023. Executive Summary of forest area information project 2023. Royal Forest Department, Bangkok. https://www.forest.go.th/land/%E0%B9%80%E0%B8%AD%E0%B8%81%E0%B8%AA%E0%B8%B2%E0%B8%A3%E0%B9%80%E0%B8%9C%E0%B8%A2%E0%B9%81%E0%B8%9E%E0%B8%A3%E0%B9%88/

Gale G and Thongaree S. 2006. Density estimates of nine hornbill species in a lowland forest site in southern Thailand. *Bird Conservation International* 16: 57–69. https://doi.org/10.1017/S0959270906000037

Gregory R, Gibbons D, and Donald PF. 2004. Bird census and survey techniques. In: *Bird Ecology and Conservation; A Handbook of Techniques*, W.J. Sutherland, I. Newton, Green R. (Eds.), Oxford University Press: 17–56.

Hornbill Specialist Group. n.d. *Hornbills of the World*. https://iucnhornbills.org/hornbills-of-the-world/

IUCN. 2024. *The IUCN Red List of Threatened Species*. Version 2023-1. https://www.iucnredlist.org/search/stats?query=hornbill&searchType=species.

Jornburom P, Chimchome V, *et al*. 2010. Density Estimation of Hornbills in Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province. *Journal of Forestry* 29(1): 1–11.

Khao Yai National Park. n.d. Bird Watching. https://www.khaoyainationalpark.com/en/plan-your-visit/thing-to-do/bird-watching

Kitamura S. 2011. Frugivory and seed dispersal by hornbills (Bucerotidae) in tropical forests. *Acta Oecologica* 37(6): 531-541. https://doi.org/10.1016/j.actao.2011.01.015

Koid QQ, Cheema S, *et al*. 2021. Observations of Hornbills in Tawau Hils Park, Sabah, Malaysia. *Hornbill Natural History and Conservation* 2(1): 3-13.

Mynott HI, Lee DC, *et al*. 2021. Population assessment and habitat associations of the Visayan Hornbill (*Penelopides panini*) in Northwest Panay, Philippines. *Avian Research* 12: 67. https://doi.org/10.1186/s40657-021-00303-3

Naniwadekar R and Datta A. 2013. Spatial and Temporal Variation in Hornbill Densities in Namdapha Tiger Reserve, Arunachal Pradesh, North-East India. *Tropical Conservation Science* 6(6): 734-748. https://doi.org/10.1177/194008291300600603

ONEP. 2017. Thailand Red Data: Vertebrates. Ministry of Natural Resources and Environment. Thailand, Bangkok. https://chm-thai.onep.go.th//wp-content/uploads/2021/12/TH-Red-Data-Vertebrates-60.pdf

Pattanavibool A, Dearden P, and Kutintara U. 2004. Habitat fragmentation in north Thailand: a case study. *Bird Conservation International* 14: S13–S22.

Poonswad P and Tsuji A. 1994. Ranges of males

of the Great Hornbill *Buceros bicornis*, Brown Hornbill *Ptilolaemus tickelli* and Wreathed Hornbill *Rhyticeros undulatus* in Khao Yai National Park, Thailand. *Ibis* 136: 79-86. https://doi.org/10.1111/j.1474-919X.1994.tb08133.x

Poonswad P, Chimchome V, *et al*. 2013. Conservation of Hornbills in Thailand. In: *Conservation Biology: voices from the tropics*, N. Sodhi, L. Gibson, Raven P. (Eds.), Wiley Blackwell: 157-166.

Poonswad P. 2008. Nest site characteristics of four sympatric species of hornbills in Khao Yai National Park, Thailand. *Ibis* 137: 183-191. https://doi.org/10.1111/j.1474-919X.1995.tb03238.x

Poonswad P. 2010. Hornbill Research in Thailand. https://www.zoo.org/document.doc?id=216

Rahayuningsih M and Nugroho E. 2013. The Distribution and Population of Wreathed Hornbill (*Aceros undulatus*) in Mount Ungaran Central Java. *International Journal of Environmental Science and Development* 4: 492-495. https://doi.org/10.7763/IJESD.2013.V4.401

Round P, Gale G, *et al*. 2005. The Ecology of Forest Birds at Mo Singto, Khao Yai. In: *Proceedings of 9th Conference of the Biodiversity Research and Training*, V. Baimai and R. Tantalakha (Eds.), Proceedings of the 9th BRT Annual Conference: 41–53.

Round P, Gale G, and Brockelman WY. 2006. A comparison of bird communities in mixed fruit orchards and natural forest at Khao Luang, southern Thailand. *Biodiversity and Conservation* 15: 2873-2891. https://doi.org/10.1007/s10531-005-2006-7.

Royal Thai Government Gazette. 2019. Wild Animal Conservation and Protection Act, B.E. 2019. https://portal.dnp.go.th/DNP/FileSystem/download?uuid=5de8b25b-4551-42f9-93a4-fed8fd-1ba9ce.pdf

Temchai T, Suksawang S, *et al*. 2014. The Forest Conversion in Dong PhayaYen-Khaoyai Forest Complex world Heritage site after World Heritage Inscription. https://www.nprcenter.com/nprc1/downloads/DPKY_report_complete4.pdf

Thailand Hornbill Research Foundation. 2022. Hornbill Nest Location. Non-published.

Thomas L, Buckland ST, *et al*. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* 47: 5-14. https://doi.org/10.1111/j.1365-2664.2009.01737.x

Tordoff AW, Baltzer MC, *et al*. 2012. Key biodiversity areas in the Indo-Burma hotspot: process, progress and future directions. *Journal of Threatened Taxa* 4(8): 2779-2787.

Trisurat Y, Chimchome V, *et al*. 2013. An assessment of the distribution and conservation status of hornbill species in Thailand. *Oryx* 47: 441–450.

UNESCO, Dong Phayayen-Khao Yai Forest Complex. https://whc.unesco.org/en/list/590/

Naphatsorn Monchaithanaphat

Vijak Chimchome

Yongyut Trisurat

Asian Hornbill Bibliography: a dynamic, online, open-access reference database for use in manuscript citations and hornbill research

T. R. Shankar Raman[1,*], Maitreyi Hegde[1], Pooja Y. Pawar[1,2], and Aparajita Datta[1]

[1] *Nature Conservation Foundation, 1311, 12th A Main, Vijayanagar 1st Stage, Mysore 570017, Karnataka, India.*

[2] *Manipal Academy of Higher Education, Manipal 576104, Karnataka, India.*

***Corresponding author**: T. R. Shankar Raman (trsr@ncf-india.org)*

Abstract

Bibliographic databases and citation tools are integral aids to research. The Asian Hornbill Bibliography presents a compendium of research on Asian hornbills by combining an open access bibliographic database with the free and open source reference manager, Zotero. The bibliography, also hosted on and made accessible from the IUCN Hornbill Specialist Group website, includes 725 publications, including books, book chapters, journal articles, reports, conference proceedings, general articles, and media reports. Here, we describe the process of parsing an initial list of references stored in a Word document to an appropriate bibliographic format and its subsequent import into a Zotero Group Library created to be public and open. Hornbill researchers can freely use the bibliography, join the Zotero Group or copy the bibliography for their use. Researchers can use Zotero plugins to insert citations in manuscripts and generate reference lists formatted in accordance with any of more than 10,000 citation styles. A static, annually updated version of the Bibliography is also available under a Creative Commons license. The Asian Hornbill Bibliography will be dynamically updated by continuously updating the database of references in the Zotero Group Library using available easy-to-use citation import tools or manual entry, if required. The Asian Hornbill Bibliography will be expanded to be an authoritative and valuable research aid for hornbill researchers worldwide.

Keywords: ornithology, bird conservation, Bucerotidae, Zotero, bibliographic database, reference manager, citation tools, research aids, open science

Introduction

Bibliographic research and referencing are both time-consuming and integral to science. Researchers need to find, collate, and read relevant prior publications, cite them appropriately in scientific manuscripts, prepare properly-formatted and detailed reference lists, and keep track of new research publications that continuously appear (Côté *et al.*, 2013; Mann, 2005). When the same tasks have to be repeated for different research studies or outputs by the same or other researchers, the cumulative effort involved can become repetitive and burdensome. Key resources and software tools that aid and simplify these tasks are bibliographic databases (which contain lists of relevant publications that can be explored or queried) and reference management software (which researchers can use to store, organise, and cite references relevant to their research). If resources or software tools are free to use and open access, they support widespread

adoption across the scientific community, even among those who cannot afford expensive commercial options.

When free and open access bibliographic databases are linked with reference management software, they provide four significant benefits for researchers.

1. Besides functioning as a freely accessible repository of past research and publications on a specific research area or species of interest, existing tools and features allow the database to be made publicly available on the internet in a form where other researchers can view, access, and/or contribute to it, or download copies for their own personal use.

2. As the reference management software reads metadata (such as author names, year of publication, abstracts, keywords, tags, and digital object identifiers or DOIs) into the database, users can filter references by metadata variables, read the text of abstracts, or access the full reference using direct links to websites where they are available.

3. Reference manager software also have installable plugins for commonly used word processors (such as Word in Microsoft Office, Writer in LibreOffice, and GoogleDocs), which allow researchers to directly insert stored references at relevant places in their manuscripts and generate reference lists automatically formatted in specific citation styles.

4. Web browser plugins and citation importing tools allow users to easily and directly update these databases by adding new references on the fly, without needing to manually enter or copy the author name(s), title, publication details, and other metadata.

Here, we describe the creation of a bibliographic database on Asian hornbills (Aves: Bucerotidae) integrated with the Zotero reference management software (https://www.zotero.org) as a free, open access resource available for use by hornbill researchers worldwide. The database is designed not as a static resource but as a dynamic database periodically updated online. At present, the database contains a compilation of scientific research publications and other literature on all 32 species of Asian hornbills till 2023. The bibliography is hosted as a live version on the website of the IUCN Hornbill Specialist Group (IUCN HSG, https://iucnhornbills.org/bibliography) and a static version (to be periodically updated) is also available for download (Datta *et al.*, 2024). Here, we describe how the bibliography was created and imported into Zotero and how hornbill researchers can make best use of this resource.

Origin of the Bibliography

The bibliography began as a compilation of references in a Word document and associated worksheet (Excel or Googlesheet) prepared by Aparajita Datta (AD) and Maitreyi Hegde (MH). The references were compiled from an existing list of publications available with AD since 2014, supplemented by extensive searches by MH on Google Scholar, Web of Science, and Scopus to manually add references (using keywords for hornbills and for particular Asian species). A few resources were collected directly from these authors and a selection of popular articles mostly shared by AD and Bee Choo Strange were included. Together, AD and MH compiled literature related to Asian hornbills, which resulted in 670 references, excluding a few hornbill posters.

Limitations of Word and Excel compilations

Although a Word document listing references is useful as a starting point, this bibliography-as-text is a static document. Created manually and organised in alphabetical arrangement by author, it offers a single view that cannot be easily or automatically rearranged; for instance, to be viewed chronologically or by other variables such as journal name or metadata tags (e.g., species). It also has limited search capability to locate references using the Find (Ctrl-F) search box within the word processor. Once a particular reference is located, it has to be copied and pasted into manuscripts or other working documents and manually reformatted to conform to other citation styles.

The Excel version of the Asian hornbill Bibliography had the same details entered although separated into different fields (columns). This enabled basic filtering and sorting besides import into similar tools such as AirTable for filtered and sorted views. For researchers intending to insert these references in manuscripts, the references are even more difficult to use from the worksheet because the full citation is distributed as separate elements in different columns, which typically pastes into Word documents as tables. They need additional work after copy-pasting into manuscripts to remove tabular elements and conform to citation styles. Although the references were carefully compiled, checked for errors, and corrected, some errors remain in the Word and Excel documents from the manual entry of each reference. These documents typically contain minor formatting or typographical errors that vary from reference to reference—such as related to author initials or names, or inconsistent use of DOI (https://doi.org/10.1111/example) or just as the slug (10.1111/example), and so on.

Many relevant metadata fields were missing in some or all the references in the bibliography-as-text Word documents and Excel worksheets, such as Abstracts and the DOI or URL links to webpages carrying the source publication. Relevant fields (such as journal name, volume and page numbers) were also not separated out as fields and would require manual editing and formatting if they needed to be used in other citation styles.

Parsing references for import into a bibliographic database

For the Asian Hornbill Bibliography (Word document) to become more useful, we needed to parse and transform the references into standard bibliographic formats that would allow their import into reference management software. A good choice of standard reference format is BibTeX (https://www.bibtex.org), which is a tool and a file format used to describe and process lists of references. Although BibTeX is often used with LaTeX documents, a reference downloaded in BibTeX format can also be imported into virtually any reference manager software and used for formatting lists of references. The reference(s) in BibTeX format are saved as a file with a '.bib' extension, which is a plain text document that can also be opened and viewed with any text reader.

To parse the Asian Hornbill Bibliography (Word document) into BibTeX format, we used the free, online resource, AnyStyle (https://anystyle.io/; ver. 1.3.14). This allowed us to simply paste the list of references in batches of 200 into the text box area (one reference per line with a line break at the end; blank lines are ignored). The parser split each reference into constituent fields (title, author, year, journal and so on). The output was saved as a BibTeX file for importing

the references into a reference manager. Although AnyStyle has some on-screen error-correction or editing capability, we largely ignored this and did the final corrections, if any, in the chosen reference manager software.

The parsing was intended as a one-time effort to extract references, after which the Word document was retired. Subsequent edits, revision, and updating of the bibliography was carried out exclusively through the reference manager software, Zotero (https://www.zotero.org).

Choice of Zotero as reference manager

A large number of tools are available for managing references, as documented in detail in 'Comparison of reference management software' on Wikipedia (Wikipedia contributors, 2024). From these, we chose Zotero for a number of reasons. Zotero is a free and open-source tool developed as a project of the Corporation for Digital Scholarship, a non-profit organization dedicated to the development of software and services for researchers and cultural heritage institutions. All essential functionality comes at no cost to researchers who can create free accounts (with up to 300 MB storage space; more storage can be purchased if required at modest pricing). Zotero can be used on the web (by logging in on https://www.zotero.org/ on a browser) or using a Desktop client installed on the user's computer or laptop (https://www.zotero.org/download). The Zotero reference library on the user's computer syncs seamlessly with their online library. Folders can be created to organise the references. Zotero has an active developer community, well-documented support and knowledge base (https://www.zotero.org/support/), and a helpful community forum (https://forums.zotero.org/discussions). The Zotero code and Wiki content are open source materials available under free licenses such as Gnu GPL and Creative Commons.

Zotero offers plugins that allow inserting citations and generating reference lists within commonly used Word processors (Microsoft Word, LibreOffice Writer, GoogleDocs) and statistical software (RStudio comes with native Zotero integration). There is support for over 10,000 citation styles, including most commonly used journal styles. Zotero has browser plugins (for Firefox, Chrome, Edge, and Safari; https://www.zotero.org/download/connectors) that allow one to save viewed references from various websites to their Zotero libraries directly from your web browser. This automatic capture of references reduces the tedium of manually copying out references and relevant details from webpages or PDF files and also by-and-large reduces errors. It also automatically saves relevant metadata in corresponding fields (year, journal or publication name, DOI, abstract, and so on). It comes with a PDF reader, note editor, and ability to import publication data from PDF files.

Finally, Zotero allows the creation of 'Groups' through which multiple researchers can collaborate on creating, using, and sharing reference libraries (https://www.zotero.org/groups). The Asian Hornbill Bibliography was created as a Zotero group in April 2023 at https://www.zotero.org/groups/4777134/asian_hornbill_bibliography, with the group library at: https://www.zotero.org/groups/4777134/asian_hornbill_bibliography/library.

The settings are presently configured for the library to be open to the public. Anybody can search the 'Asian Hornbill Bibliography,' view and download references, or join the group. The group owner (IUCN HSG) and group admins (presently Pooja Y. Pawar and T. R. Shan-

kar Raman) can edit group settings, and the ability to add, edit, or delete references in the library is restricted to the admins. The steps involved in the creation of the Asian Hornbill Bibliography from the original Word document into a Zotero Group Library are illustrated in Fig. 1.

Asian Hornbill Bibliography – Zotero Group library

After editing, correcting, and removing duplicates from the original 670 references, a number of recent references were imported and added to the database, including all papers on

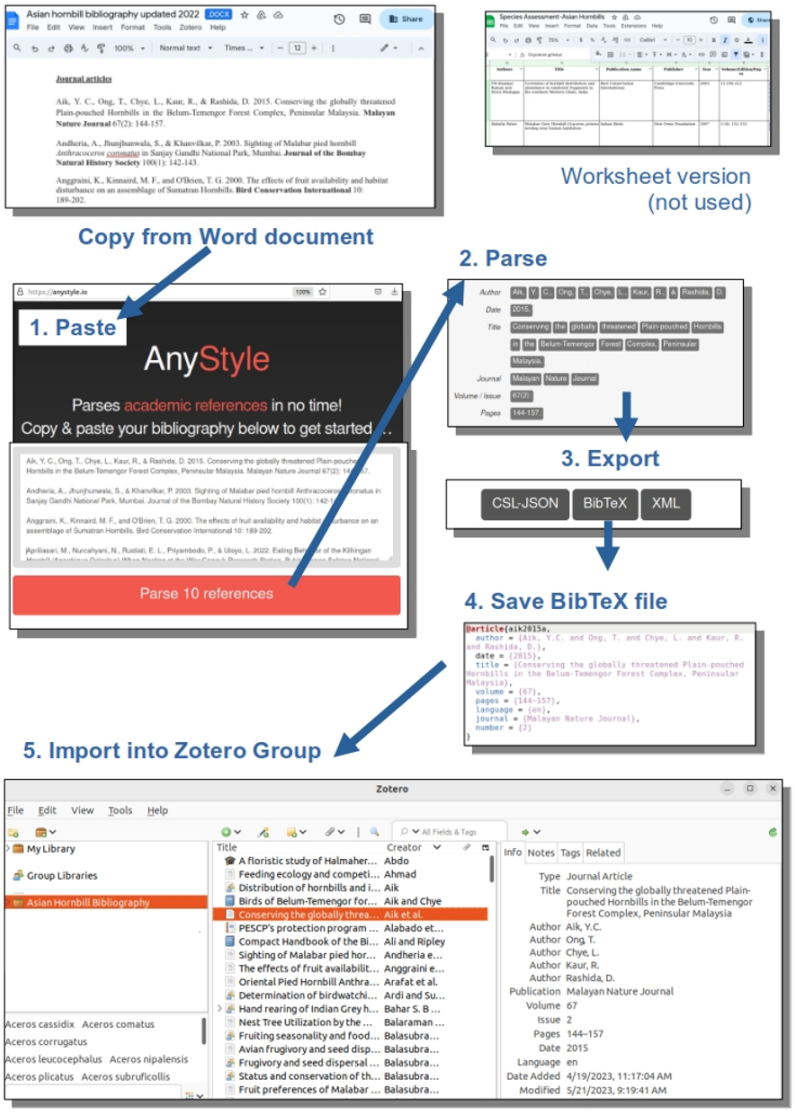

Fig. 1. Steps involved in creation of Asian Hornbill Bibliography from a listing of references in a Word document.

Asian hornbills published in the first four volumes of the IUCN HSG journal *Hornbill Natural History and Conservation*. As a result, the Zotero group library holds at present (13 March 2024) a total of 725 references. These 725 references include 496 peer-reviewed journal articles, 24 reports, 19 theses, 24 books, 24 book chapters, 47 newspaper and magazine articles, 83 conference proceedings, and 5 general documents, a film (video), the Bibliography of South Asian Ornithology (Pittie, 2023) and the static Version 1.0 of the present bibliography (Datta *et al.*, 2024). Excluding the static version, the references date back to a single paper in 1902 and then from the 1950s up to 2023. The highest number of publications on hornbills were published in the decade 2011 – 2020 (321 references including 220 journal articles). The bibliography includes a majority of papers on abundance and distribution, besides publications on behaviour, habitat ecology, feeding ecology, breeding and nesting ecology, conservation and management, threats, captive breeding, and systematics and evolution.

Live IUCN HSG webpage for the Asian Hornbill Bibliography

To create a live, online view of the Bibliography including the latest updates (if any), we integrated the bibliographic database in the Zotero group library into the website of the IUCN SSC Hornbill Specialist Group (IUCN HSG). To do so, we first linked the Zotero group library with BibBase (https://bibbase.org/start) and then embedded the following script into the IUCN HSG website page:

<script
src="https://bibbase.org/show?bib=https://bibbase.org/zotero-group/iucnhs-g/4777134&msg=embed#"></script>

As a result, the Asian hornbill bibliography maintained in Zotero can now be dynamically viewed online on the IUCN HSG website under the 'Resources' tab at this URL: https://iucnhornbills.org/bibliography/

The database may take a few seconds to load as it has over 720 references. The references can be viewed by Author (the default), Year, Type (journal article, book, etc.), or keywords (here, the scientific name of Asian hornbill species, or "General" for other general references). The scientific name was used as Keyword so that people can easily view references aggregated by species. The Keywords on the IUCN HSG webpage view correspond to 'Tags' in Zotero. For publications dealing with more than one species, each scientific name was entered as a separate Tag for that reference. Such references appear multiple times in the IUCN HSG bibliography webpage, once under each of the corresponding species ('Keyword').

Publishing the static current version

The current version of the database was published on the open science repository, Zenodo (Datta *et al.*, 2024). This repository, intended to be annually updated to the latest version of the database, contains the original Word and Excel files, the bibliography as saved on Zenodo, and a new Word document version generated in a standard citation format from the Zenodo library reflecting corrections to references, if any. The following files are available in Datta *et al.*, (2024):

1. A README.txt file containing general information and instructions: text file
2. Original word processor document of the Asian Hornbill Bibliography: a Microsoft Word/LibreOffice Writer file with '.docx' extension

3. Original worksheet file of the Asian Hornbill Bibliography: a Microsoft Excel/libreOffice Calc file with '.xlsx' extension
4. BibTeX file of the database downloaded from the Zenodo library: readable also as a text file with '.bib' extension
5. A new document in RTF or rich-text format ('.rtf' extension) generated from the Zenodo group library, readable in most word processors
6. An HTML version of the bibliography in alphabetical order of title—a browser viewable HTML version with '.html' extension

The bibliography file was generated by using the 'Export Library' option in Zotero and saved as a BibTeX file (.bib). The new word processor RTF version was generated using the 'Create Bibliography' option with all 725 items selected. The HTML version was created using the 'Generate Report' option with all items in the library selected.

Updating the Asian Hornbill Bibliography

The bibliography needs to be updated with both overlooked older references and newer publications. Where the source publication is on a website that allows export/saving of the reference as a BibTeX file, Zotero can import references from the saved .bib file. The Zotero browser connector plugin can also be used as on many websites, including journal websites, to directly import the reference with a few clicks. For publications that are not available on the web or in any database or BibTex format, there are two options to update the database: direct manual entry in Zotero (Add Item) or using AnyStyle (https://anystyle.io) to parse a plain text reference into a BibTeX file for import into Zotero. Once imported, appropriate tags such as scientific name of hornbill species need to be added.

At present such edits and updating can only be carried out by the Zotero group admins. We intend to open it to all Zotero Group members eventually. If made fully open at present, references may get inadvertently deleted and thereby lost from the database, since it is not possible to restrict deletion rights. Until such a Zotero feature is available or automatic backup or versioning are possible, the library editing rights will remain restricted to admins. Hornbill researchers interested in joining as admins to contribute to maintaining and updating the database can get in touch with the IUCN Hornbill Specialist Group (Contact: IUCN HSG Programme Officer, E-mail: programme.officer.hsg@gmail.com) with an expression of interest.

Once a year, a static version of the entire Bibliography will be published to Zenodo to update Datta *et al.*, (2024) as a new version.

Using the Asian Hornbill Bibliography

Hornbill researchers and others can use the Asian Hornbill Bibliography in the following ways (Fig. 2). For maximum ease of use, we suggest that users also have Zotero accounts, install the Zotero desktop version on their computers, and install two key plugins (Zotero connector plugin for their browser and Zotero plugin for their word processor).

1. **Searching for hornbill literature:** Users can search the bibliography for relevant literature by visiting the main Zotero group landing page and navigating to the Zotero group library here: (https://www.zotero.org/groups/4777134/asian_hornbill_bibliography/library). On the library page, they can enter into the Search box particular search terms or keywords to find related publications.

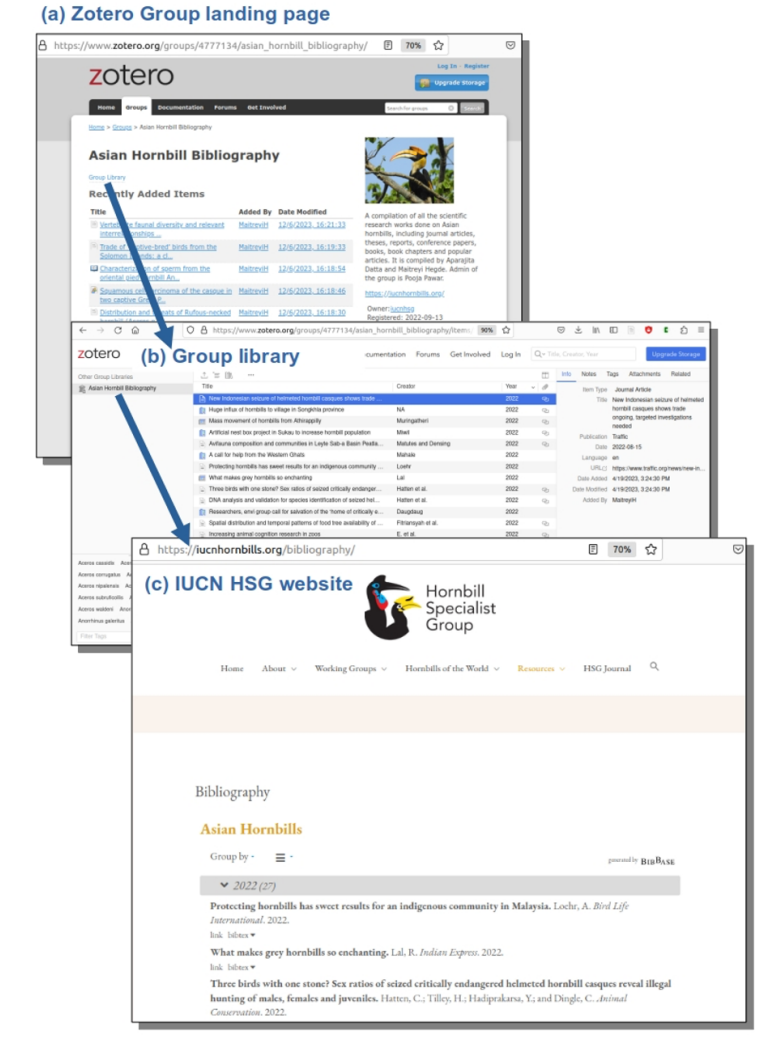

Fig. 2. Multiple ways to access the Asian Hornbill Bibliography including: (a) viewing the Zotero Group main landing page where users can join as members, (b) exploring the Zotero Group Library page that allows users to search and export references, and (c) exploring filtered views on the IUCN HSG website.

2. **Exploring the IUCN HSG Asian Hornbill Bibliography page:** on the IUCN HSG Resources page where the Asian Hornbill Bibliography can be viewed: https://iucn-hornbills.org/bibliography/, users can sort listings and access links to the references. Using the dropdown filter, the references can be viewed by Author (default), Year, Type (journal article, book etc.), or by hornbill species (keywords, arranged by scientific name). Where Abstracts are available in the database, they can be viewed directly below the reference. Clicking on the DOI or URL link icons below the reference will open the corresponding website page containing the referenced publication.

3. **Saving the database for personal or offline use:** Users can join the Zotero group library (https://www.zotero.org/groups/4777134/asian_hornbill_bibliography/) as members by clicking the 'Join' button. Once synced, this will create a copy of Asian Hornbill Bibliography as a folder under 'Group Libraries' in

the Zotero application on the user's computer. If you wish to make a copy for personal use without joining the Zotero group, the entire bibliography can be exported from the group library page and saved as a BibTeX file (or other formats), which the user can subsequently import into their personal library ('My Library') in the Zotero application or in most other reference manager software.

4. **Using citations in manuscripts:** Once users have joined the Zotero group as members and have the bibliography synced in their Group Library (or downloaded a copy into My Library without joining the group), they can use the references directly in manuscripts. The word processor plugins allow the user to insert, edit, rearrange or delete a reference or sets of references in the main text. The user can also generate a full bibliography automatically formatted to match any chosen journal or publication citation style at the appropriate place in the manuscript.

5. **Contributing to updating the database:** The users can also contribute to updating the database by suggesting changes or corrections to existing references or addition of newer publications using the online form (https://forms.gle/5VFj9bbPZA1vXaHt5) available on the IUCN Asian Hornbill Bibliography page (https://iucnhornbills.org/bibliography/). We aim to update this dataset regularly.

6. **Creating derived resources:** The Asian Hornbill Bibliography, both the static version (Datta *et al.*, 2024) and the dynamic online version (Zotero Group Library) are provided under open access licenses (Creative Commons with Attribution 4.0 or CC-BY 4.0). Users can thus download the bibliographic database and create derivative resources (such as hornbill bibliographies on particular species, study areas, or themes) under the terms of the CC-BY 4.0 license.

Conclusion and future work

The Asian Hornbill Bibliography serves as a valuable resource for hornbill researchers and other tropical biologists worldwide. This bibliography will also be useful for non-scientists, science communicators, journalists, and the general public interested in hornbills and topics related to tropical forests. Leveraging the power of free and open source tools and resources, the bibliography provides an accessible entry point to the body of literature on Asian hornbills. It provides a standard, relatively error-free, and convenient way to reference hornbill literature in scientific publications and manuscripts, thereby saving researchers from repetitive tasks and time-consuming manual citation practices. We aim to expand and enhance the database in future to serve as an authoritative and regularly updated compendium of hornbill research, besides including other relevant items such as general articles, webpages, posters, educational resources, and audio-visual material on Asian hornbills. The bibliography can also be combined with similar compilations of literature on African hornbills to create an authoritative bibliography on hornbills of the world.

Acknowledgements

This work was supported by a grant to the IUCN SSC Hornbill Specialist Group from Mandai Nature, Singapore. We thank Dr. Sonia Luz and Dr. Jessica Lee of Mandai Nature for their support. We thank Elizabeth Zadnik and Bee Choo Strange for their inputs for the database. TRSR was supported by a grant from Rohini Nilekani Philanthropies to NCF.

References

Côté IM, Curtis PS, Rothstein HR and Stewart GB. 2013. Gathering Data: Searching Literature and Selection Criteria. In: *Handbook of Meta-analysis in Ecology and Evolution*, J. Koricheva, J. Gurevitch and K. Mengersen (Eds.). Princeton University Press, Princeton: 37–51. https://doi.org/10.23943/princeton/9780691137285.003.0004

Datta A, Hegde M, Pawar PY and Raman TRS. 2024. *Asian Hornbill Bibliography*, Version 1.0. IUCN Hornbill Specialist Group. Dataset, Zenodo. https://doi.org/10.5281/zenodo.10820070

Mann T. 2005. *The Oxford Guide to Library Research*. Oxford University Press, USA. https://doi.org/10.1093/oso/9780195189971.001.0001

Pittie A. 2023. *Bibliography of South Asian Ornithology*. Retrieved July 6, 2024, from http://www.southasiaornith.in/.

Wikipedia contributors. 2024. Comparison of reference management software. In *Wikipedia, The Free Encyclopedia*. Retrieved July 6, 2024, from https://en.wikipedia.org/w/index.php?title=-Comparison_of_reference_management_software&oldid=1226337734.

T. R. Shankar Raman

Maitreyi Hegde

Pooja Y. Pawar

Aparajita Datta

Roosting patterns of hornbills in Buxa Tiger Reserve in the Indian Eastern Himalaya

Shilpita Mandal[1,*], Dollar Ganguly[1,2], Karishma Pradhan[3], Sitaram Mahato[1], Kezajacho Dukpa[1], Arkajyoti Shome[1,4], Arjan Basu Roy[1], and Aparajita Datta[3]

[1] *Nature Mates-Nature Club, 6/7 Bijoygarh, Kolkata, West Bengal, India 700032*

[2] *Svasara Jungle Lodge, Chimur, Kolara Gate, Chandrapur, Maharashtra, India 442903*

[3] *Nature Conservation Foundation, 1311, Amritha, 12th Main, Vijaynagar 1st Stage Mysore, Karnataka, India 570017*

[4] *The Energy & Resources Institute, Lodhi Road, New Delhi, India 110003*

***Corresponding author:** Shilpita Mandal (shilpitamandal0401@gmail.com)*

Abstract

*Communal roosting is an interesting behaviour observed in many hornbills. We located seven roost sites of Great Hornbill (*Buceros bicornis*) and Wreathed Hornbill (*Rhyticeros undulatus*) at Buxa Tiger Reserve, India. We monitored these sites from 2018 to 2023 to determine roosting patterns and yearly trends in numbers. Two roost sites were regularly monitored in the non-breeding season. In 2022 and 2023, we also carried out monitoring during the breeding season. The hornbill numbers, the sex/age of birds, and the first and last arrival times were recorded. During the non-breeding season, the mean number of Great Hornbills roosting in hill forests was 6 ± 0.78 (range:1–20), while the mean number of Wreathed Hornbills roosting along a riverbank was 42 ± 7.26 (range:1–224). The range in breeding season numbers for Great Hornbills was 1–7 birds, while for Wreathed Hornbill, it was only one bird. Hornbills arrived an hour earlier in winter than in summer. Great Hornbills usually arrived together, close to or after sunset, while Wreathed Hornbill flocks arrived over an extended period, with most arriving 10–40 minutes before sunset. This study highlights the differences between hornbill species in roosting behaviour and habitats used for roosting. Long-term monitoring helps to understand the trends in numbers of hornbills using the roost sites, observe patterns in behaviour over time and potential threats to these critical habitats enabling conservation actions. Monitoring these sites can provide insights into the habitat quality, including any natural or anthropogenic changes in vegetation, such as loss of roost trees.*

Keywords: *Buceros bicornis*, Great Hornbill, *Rhyticeros undulatus*, roosting behaviour, roost site, Wreathed Hornbill

Introduction

Roosting is a natural behaviour of animals resting/sleeping for the night. A roost can be defined as a place where animals select a suitable place and rest for the night or during their non-active period (e.g., nocturnal species roost during the day). Many animals spend a significant part of their life at roosts.

Wreathed Hornbills flying to roost site at the Bala river bank in the Buxa Tiger Reserve, West Bengal, India. Photo: Sitaram Mahato

Wreathed Hornbills roosting on a *Bombax ceiba* tree in the Buxa Tiger Reserve, West Bengal, India. Photo: Sitaram Mahato

Communal roosting is a phenomenon where numerous individuals of the same or different species congregate in a designated location every night to rest. Among birds, this behaviour is predominantly displayed by social or gregarious bird species like crows, cormorants, harriers and starlings. It is hypothesised that roosting serves multifaceted purposes—1) information centres to determine location of food sources (Ward and Zahavi, 1973; Johnston-González and Abril, 2019); 2) an anti-predatory strategy where there is a safety in numbers (Weatherhead 1983; Bock *et al.*, 2013); 3) habitat preference based on breeding and non-breeding season (Zoghby *et al.*, 2016); 4) a thermoregulatory mechanism to conserve heat (Canals *et al.*, 1989, 1998; Gilbert *et al.*, 2010); 5) kin selection benefits (Rabenold, 1986; Parker *et al.*, 1995); 6) mate choice and anthropogenic disturbances (Peter and Otis, 2007); 7) anti-parasitic response (Rohner *et al.*, 2000).

Hornbills roost singly, in pairs, small flocks or large flocks (>5 to more than 2000) (Poonswad *et al.*, 2013). Of 62 extant hornbill species, 26 are known to roost in small flocks or large communal roosts (Kemp, 1995; Datta, 2001). Some hornbill species exhibit communal roosting with the same sites used over many years, with

Wreathed Hornbill pair perching on a roost tree branch in the Buxa Tiger Reserve, West Bengal, India. Photo: Sitaram Mahato

Great Hornbill roosting on a *Bombax ceiba* tree in the Buxa Tiger Reserve, West Bengal, India. Photo: Sitaram Mahato

visits occurring consistently or intermittently across months in a given year. Telemetry studies have shown that several hornbill species prefer riverine habitat for roosting and show site fidelity (Zoghby *et al.*, 2016; Naniwadekar *et al.*, 2021). The most remarkable instances of communal roosting can be observed among Plain-pouched Hornbills (*Rhyticeros subruficollis*), where reports indicate congregations of 2000–3000 individuals in Malaysia (Ho and Supari 2000; Kaur *et al.*, 2011).

Communal roosting has been reported in Great, Oriental Pied and Wreathed Hornbills from western Arunachal Pradesh (Datta, 2001; Naniwadekar *et al.*, 2021). They were seen to roost in open grasslands along riverbanks or on cliffs with fewer trees near rivers and perennial streams. The counts of birds in these roosts along the riverside exhibited seasonal variations, with fewer birds observed during the breeding season than in the non-breeding season (Datta, 2001). Mixed-species communal roosting was seen with Great and Wreathed Hornbills using the roost together in the Pakke Tiger Reserve (Datta and Rane, 2011).

There was no prior information on the roost sites used by hornbills and their roosting patterns in northern West Bengal in the Eastern Himalayan region. This paper presents information on the roost sites of hornbills in the Buxa Tiger Reserve and focuses on describing and understanding the seasonal and annual trends in numbers and roosting patterns of the Great Hornbill and Wreathed Hornbill, determining the age and sex composition of roosting flocks, describing the patterns in roost arrival times of hornbills and assessing if the roost sites are continually used through long-term monitoring. The long-term roost monitoring helps to understand the seasonal and annual trends in the numbers of hornbills using the roost sites and observe patterns in behaviour over time, contributing to our understanding of hornbill biology.

Methods

We conducted our study in Buxa Tiger Reserve (BTR; 89°23′–89°53′ E and 26°34′–26°46′ N) in the foothills of the Eastern Himalaya of West Bengal, India. The Tiger Reserve/National Park encompasses an area of 760.87 km^2, of which 390.58 km^2 has been constituted as Wildlife Sanctuary and National Park and the remaining 370.29 km^2 as Reserved Forests and other Protected forests. The core area of BTR is 417.55 km^2 and the buffer zone is 343.32 km^2 (Bhaskar and Rai, 2016) The entire BTR falls within the Eastern Himalaya Biodiversity Hotspot. Its northern boundary runs along the international border with Bhutan and the eastern boundary of the reserve is shared with the state of Assam. The reserve is situated at the confluence of three major biogeographical regions, as identified by Rodgers and Panwar (1988): the Lower Gangetic Plains, the Central Himalaya, and the Brahmaputra Valley. The main forest types in Buxa TR are Sub Himalayan Wet Mixed Forest, East Himalayan Upper Bhabar Sal, East Himalayan Moist Mixed Deciduous Forest and Plantations (Champion and Seth, 1968). Most of the reserve area lies in the plains, but the northern parts are hilly. The altitude ranges from 65 to 1750 meters above sea level. Many perennial rivers and streams, like the Sankosh, Raidak, Jayanti, and Dima rivers, flow through the reserve. The reserve has immense ecological and geomorphological significance and rich floral and faunal diversity. Over 359 bird species have been documented in the BTR and it is a designated Important Bird Area in West Bengal (Birdlife International, 2023). BTR is known for its five resident hornbill species: Great Hornbill (*Buceros bicornis*), Oriental Pied Hornbill (*An-*

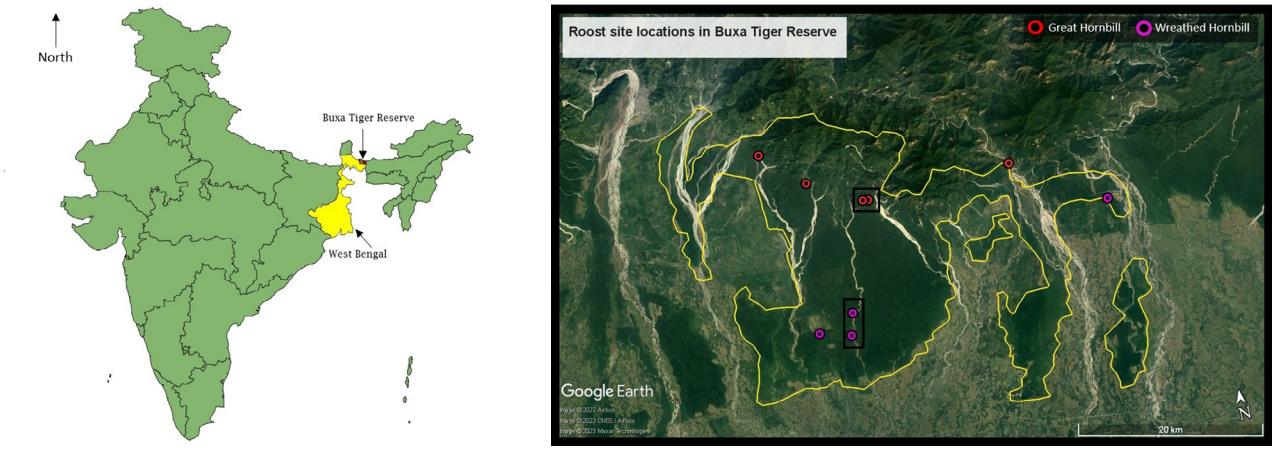

Fig. 1. Great Hornbill (red circles) and Wreathed Hornbill (violet circles) roost sites identified in Buxa Tiger Reserve, West Bengal, India. The boxed circles are the roost sites that have been monitored regularly in this study (yellow line indicates the BTR boundary).

thracoceros albirostris), Indian Grey Hornbill (*Ocyceros birostris*), Wreathed Hornbill (*Rhyticeros undulatus*) and Rufous-necked Hornbill (*Aceros nipalensis*). The Indian Grey Hornbill is occasionally reported from near human habitation/agricultural areas and forest edges (eBird). Habitat loss and degradation, fragmentation and poaching of chicks are key threats to hornbill populations in the region. BTR has 37 forest villages and is surrounded by 42 revenue villages and 34 tea gardens (Bhaskar and Rai, 2016). The various ethnic groups that reside here are Nepali, Rabha, Oraon, Santhal, Mech, Garo, Dukpa, and other mixed communities are also present (Das, 2005). Sal (*Shorea robusta*), teak (*Tectona grandis*), jarul (*Lagerstroemia speciosa*) were commonly grown as monoculture plantations in the past.

We identified seven roost sites (Fig. 1) where hornbills were seen to congregate during evenings. We located the roost sites by following flocks of hornbills or by locating piles of regurgitated seeds dropped by hornbills when they perch for the night under several trees. Four of the seven roost sites are of Great Hornbill (Fig. 1), and three are of Wreathed Hornbill (Fig. 1). All four Great Hornbill roost sites are in moist mixed deciduous hill forests close to small water bodies like ponds or waterholes. The three Wreathed Hornbill roost sites are located along river banks. After locating a roost site, we record characteristics such as roost tree species, number of trees used as roosts, GPS (Global Positioning System) coordinates of the roost trees, GBH (Girth at Breast Height), height of the roost trees, altitude and habitat type of the site.

We monitored one Great Hornbill roost site and one Wreathed Hornbill roost site at least once a fortnight in the first two years, followed by weekly monitoring in subsequent years. The remaining five roost sites were opportunistically monitored as they were located far away. We have been monitoring one Great Hornbill roost site and one Wreathed Hornbill roost since 2018 and 2019, respectively. The Great Hornbill roost site was monitored during the non-breeding months in 2018, 2019, 2020, 2021, and throughout the year in 2022 and 2023. The nest entry dates of Great Hornbills in Buxa TR, based on six years of nest monitoring, indicated that the Great Hornbill breeding season started from the end of February/ March. Based on chick exit dates, the breeding

season continued till June/early July (Ganguly *et al.*, 2022; Pradhan *et al.*, 2023). Therefore, February–March was considered the transition period from non-breeding to breeding season and July as the transition between breeding and non-breeding season for Great Hornbills.

The Wreathed Hornbill roost site was monitored during the non-breeding months in 2019, 2020, 2021, and throughout the year in 2022 and 2023. For the Wreathed Hornbill, the breeding season commenced in March or April and extended until the end of July or August (Ganguly *et al.*, 2022; Pradhan *et al.*, 2023). Therefore, March–April were considered as the transition months from non-breeding to breeding and August as the transition month between breeding to non-breeding season. The transition period data was also crucial in our study to show that hornbills did not abruptly stop coming to these roost sites with changes in their reproductive/nesting status. We monitored the roost sites only in the non-breeding season (September to January) from 2018 to 2021. We started year-round monitoring from 2022 onwards.

We visited the roost sites from 15:00–16:00 till 17:00–18:00, depending on the season and day length. We observed and counted hornbills arriving at the roost sites. We noted the sex/age (adult/juvenile) when possible. We also noted the first arrival times and the last arrival times to the roost sites. We also recorded the activity of other hornbill species—the Oriental Pied-Hornbill and Rufous-necked Hornbill near these roost sites to determine if they could be potential roost sites for them as well. All the counts were taken from a slightly hidden place with binoculars (10×40) to ensure that no hornbills were aware of or disturbed by our presence. We took pictures and videos to document the hornbills at these roost sites.

This paper presents the data on roost counts from 2018 to 2023. We calculated mean roosting numbers for each species in the non-breeding and breeding seasons, examined the composition of roosting flocks and the differences shown by the two species in their arrival times to the roost site in relation to the daily sunset times for this period that is available for Alipurduar district.

Results

We have 213 days of observations across seven identified roost sites of Great and Wreathed Hornbills between 2018 and 2023 (up to August). Our present study focuses on one Great Hornbill roost site monitored for 94 days, and another Wreathed Hornbill roost site monitored for 95 days. The remaining five roost sites have been sporadically monitored for 24 days, recording both Great and Wreathed Hornbills. In BTR, we have not found any Oriental Pied-Hornbill and Rufous-necked Hornbill roost sites.

Roost site characteristics

The Great Hornbill roost site (called Pukhri-Tashigaon) has two locations (Fig. 1) within 700 meters, which we have considered as one roosting site. The hornbills move between these two locations for roosting over the year. The location is in mixed deciduous forest, and the Great Hornbill's roost is on two *Shorea robusta* trees and one *Albizia lebbeck* tree. The roost trees are close to a pond considered sacred and visited by tourists. At the other location, Great Hornbills roost on five trees. The roost trees are alongside a watch tower (also visited by tourists). The roost trees used here are two *Terminalia tomentosa* trees, one *Terminalia*

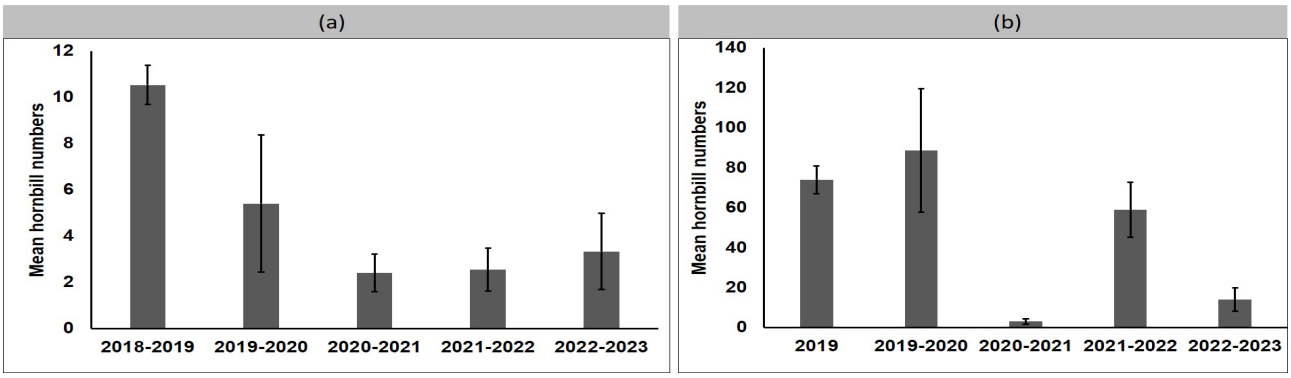

Fig. 2. Mean (± SE) numbers of hornbills in the roost sites during non-breeding season in the Buxa Tiger Reserve, West Bengal, India, from 2018 to 2023. **a.** Mean (±SE) Great Hornbill numbers in Pukhri-Tashigaon roost site during non-breeding season (August to January). n = 45 total observation days. **b.** Mean (±SE) Wreathed Hornbill numbers in 20-22 mile Bala river roost site during the non-breeding season (September – February). n = 60 total observation days.

bellirica and one *Albizia procera* tree. This habitat is moist mixed deciduous forest with a few *Shorea robusta*, *Tectona grandis* and *Terminalia tomentosa* plantations and this location overlooks a waterhole. Both the sites are 300 m from the nearest perennial stream and are within 4 km from the nearest human habitation.

The Wreathed Hornbill roost site is a stretch of 2.5 km on the bank of the Bala River (Fig. 1), where hornbills are seen to roost in multiple locations along this river bank. The main roost trees are two *Tetrameles nudiflora*, two *Terminalia tomentosa* and one *Bombax ceiba* tree. The habitat can be characterised as a riverine habitat that transitions from secondary forest near the riverbank to primary forest further inside. The details of the roost site characteristics of the two main roost sites are given in Table S1. No tourists are allowed in this part of the forest, but local people often frequent the area, while Forest Department patrolling staff reside in the watchtower at 22 mile. The length of this stretch is 2.5 km along the Bala riverbank. Wreathed Hornbills roost along this stretch in different months of the year.

Hornbill counts at roost sites

Our study showed that Wreathed Hornbills congregate in large numbers in the non-breeding season, while Great Hornbills roost in smaller groups. The overall mean (±SE) Great Hornbill numbers arriving at the Pukhri-Tashigaon roost site over all the years is 6 ± 0.8 birds (Fig. 2a). The overall mean (±SE) Wreathed Hornbill numbers in the non-breeding season at the Bala river roost site over all the years is 42 ± 7.3 birds (Fig. 2b). In the breeding season, for the Great hornbill, the overall mean (±SE) is 2 ± 1 birds while for the Wreathed hornbill, the mean is zero birds. Based on year-round monitoring in 2022 and 2023, the mean Wreathed hornbill numbers using the roost site in the non-breeding season are much higher than the numbers seen in the breeding season (Fig. 3a and 3b).

The highest number of Great Hornbills (20 birds) was seen in August 2023 (Table 1). Wreathed hornbill numbers show a drastic decline in the breeding season and the transition period, while numbers are higher in the non-breeding season, with the maximum number seen on a single day being 224 in the 2020 non-breeding

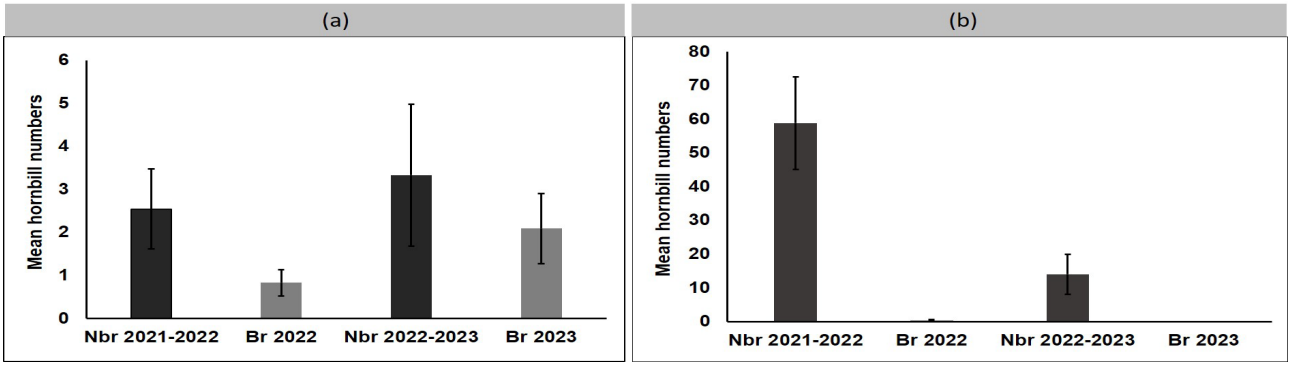

Fig. 3. Mean (± SE) hornbill numbers at roost sites in the breeding (Br, grey bars) and non-breeding (Nbr, black bars) season in the Buxa Tiger Reserve, West Bengal, India, 2021 to 2023. **a.** Mean (± SE) Great Hornbill numbers at roost sites in the breeding and non-breeding season. n = 17 total observation days. **b.** Mean (±SE) Wreathed Hornbill numbers at roost sites in the breeding (Br) and non-breeding (Nbr) season. n = 17 total observation days.

Table 1. Great Hornbill numbers seen in Pukhri-Tashigaon roost site during the non-breeding, breeding season and in transitions between them in Buxa Tiger Reserve, West Bengal, India from 2018 to 2023. (Transition 1: non-breeding to breeding season shift, Transition 2: breeding to non-breeding season shift).

Year	Season/Months	No. of days monitored	Great Hornbill number range	Mean number of Great Hornbills
2018-2019	Non-breeding (Nov-Jan)	15	5-17	11
2019-2020	Non-breeding (Nov-Jan)	5	2-14	5
2020-2021	Non-breeding (Nov-Jan)	5	2-5	2
2021-2022	Non-breeding (Sept- Jan)	11	1-11	3
2022	Transition 1 (Feb-Mar)	4	2-5	2
2022	Breeding (Apr-Jun)	6	1-2	1
2022	Transition 2 (Jul)	2	0	0
2022-2023	Non-breeding (Aug- Jan)	9	1-15	3
2023	Transition 1 (Feb-Mar)	7	2-19	7
2023	Breeding (Apr-Jun)	11	1-7	2
2023	Transition 2 (Jul)	4	5-10	4
2023	Non-breeding (Aug*)	6	1-20	9

Table 2. Wreathed Hornbill numbers seen in 20-22 mile Bala river roost site during non-breeding and breeding season and in the transition between them in Buxa Tiger Reserve, West Bengal, India from 2019 to 2023. (Transition 1: non-breeding to breeding season shift, Transition 2: breeding to non-breeding season shift).

Year	Season/Months	No. of days monitored	Wreathed Hornbill number range	Mean number of Wreathed Hornbills
2019	Non-breeding (Jan-Feb)	7	47-94	74
2019-2020	Non-breeding (Nov-Feb)	9	8-224	89
2020-2021	Non-breeding (Nov-Feb)	12	1-17	3
2021-2022	Non-breeding (Sept-Feb)	16	8-144	59
2022	Transition 1 (Mar-Apr)	4	1-44	14.5
2022	Breeding (May-July)	5	0-1	0.4
2022	Transition 2 (Aug)	1	0	0
2022-2023	Non-breeding (Sept-Feb)	16	2-80	14
2023	Transition 1 (Mar-Apr)	4	3-5	3
2023	Breeding (May- July)	12	0	0
2023	Transition 2 (Aug*)	5	0	0

season (Table 2). The hornbill counts recorded in the other five roost sites, which were opportunistically monitored, are summarised in Table 3.

Roosting flock composition

Our study showed almost an even adult sex ratio in most years for both Great and Wreathed Hornbills (Fig. 4a and 4b). For Great Hornbills in the non-breeding season, the overall percentage of males was 44%, and that of females was 35%. Similarly, for Wreathed Hornbills in the non-breeding season, the overall percentage of males was 52%, and that of females was 44%. The hornbills mostly arrive in pairs and groom each other while perching at roosts. Some arrive solitarily and some in bigger flocks as well. The percentage of juveniles ranged from 21-29% in Great Hornbills and 4-6% in Wreathed

Table 3. Hornbill numbers recorded at five roost sites that were monitored sporadically from 2019 to 2023 in the Buxa Tiger Reserve, West Bengal, India.

Species	Roost Site location	No. of days monitored	Range of hornbill numbers seen
Great Hornbill	Jorpukhri, Bhutanghat	8	2-7
Great Hornbill	Adma Bison Tower, Raimatang	1	16
Great Hornbill	Toribari Pukhri	1	4
Wreathed Hornbill	Bounibasti, 21 Mile	10	2-8
Wreathed Hornbill	Sankosh riverbed, Kumargram	4	61

Hornbills. There appears to be a higher proportion of juvenile Great hornbills seen than juvenile Wreathed hornbills, and this could be indicative of limited nesting of Wreathed hornbills in the study site (unpubl. data). However it is unclear whether this reflects a real difference in juveniles recruiting into the population because in some of the initial years, juveniles were not identified with surety, especially in the case of Wreathed Hornbills. Our present observations do not provide an accurate understanding of the proportion of juveniles in the roosting flocks as the age/sex of many remain unclassified; however, it would be greater than the reported percentages.

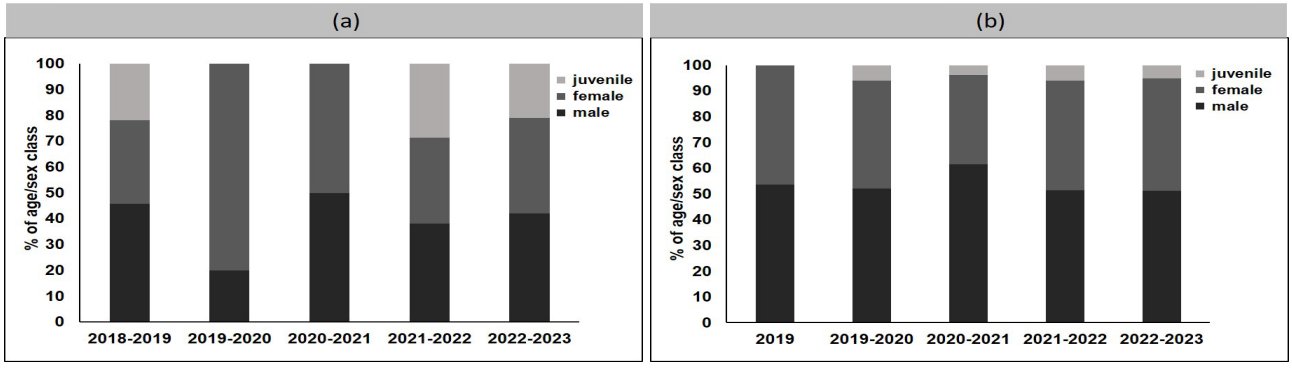

Fig. 4. Roosting flock composition of hornbills in the non-breeding season in the Buxa Tiger Reserve, West Bengal, India. **a.** Percentage of Great Hornbill males, females, juveniles in roosting flocks in the non-breeding season. n = 147 individuals classified. **b.** Percentage of Wreathed Hornbill males, females, juveniles in roosting flocks in the non-breeding season. n = 1394 individuals classified.

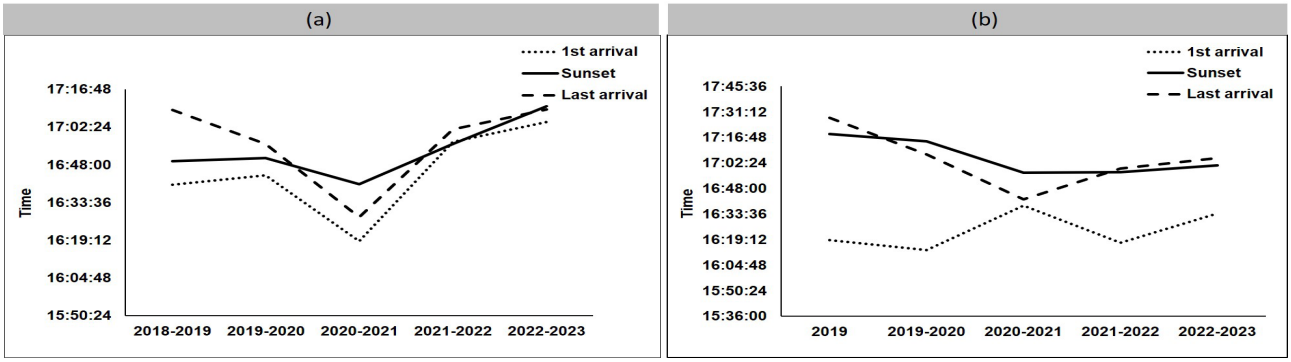

Fig. 5. Hornbill roost arrival times in relation to the sunset timings in the Buxa Tiger Reserve, West Bengal, India **a.** Great Hornbill roost arrival times in relation to the sunset timings. n = 63 observation days in the non-breeding season. **b.** Wreathed Hornbill roost arrival times in relation to the sunset timings. n = 58 observation days in the non-breeding season.

Roost arrival times

In the winter months (November to February), the sunset time ranged from as early as 16:39 hours in December to 17:29 hours in February. In the summer months (March to May), sunset time ranged from 17:34 to 18:17 hours and in monsoon months (June–July), sunset time ranged from 18:21 to 18:28 hours. There is almost a two-hour difference in sunset times between different seasons.

Seasonal variation in the mean first and last arrival time was observed in both species. In 66% of sightings, Great Hornbills started arriving at the roost site about 15 minutes (SE ± 3) before sunset, and in 27% of sightings, Great Hornbills arrived at about 14 minutes (SE ± 4 after sunset in the non-breeding season (August–January). In seven percent of sightings, they were observed to arrive exactly at sunset. Therefore, our observations of non-breeding season show that Great Hornbills tend to arrive briefly around sunset or shortly after sunset (Fig. 5a).

In 94% of sightings, Wreathed hornbills started arriving about 38 minutes (SE ± 4) before sunset, and only in 4% of sightings they arrived after sunset in the non-breeding season (September-February). There was only one instance when two hornbills arrived at sunset. Thus, in contrast to Great Hornbills, who arrive close to sunset, we observed Wreathed Hornbill flocks displaying a rather extended arrival time of about 38 minutes before sunset (Fig. 5b). These observations show a noteworthy difference in the arrival behaviour of these two hornbill species during the non-breeding season.

Detection of other hornbill species in the identified species-specific roost locations

In the Pukhri-Tashigaon Great Hornbill roost site, we recorded 12 instances where Oriental Pied-Hornbills and Wreathed Hornbills flew near the exact roost site. On one occasion, a juvenile Wreathed Hornbill roosted at this site when Great Hornbills did not use the site for roosting. Additionally, we observed Rufous-necked Hornbills (flock size = 4) perched on these roosting trees on two separate occasions before eventually flying off to their likely final roosting sites. In the vicinity of the 20–22-mile Bala river bank, where Wreathed Hornbills typically roost, we recorded 28 instances when we encountered Oriental Pied-Hornbills (ranging from 17 to 30 individuals) taking flight together from some trees. Some Oriental Pied-Hornbills were often seen perched on a few trees, sometimes on the

opposite bank of the Bala River, foraging during the pre-roosting hours and then flying away to another location. This can indicate that the Oriental Pied-Hornbill roost site might be nearby. We observed a single instance of a Great Hornbill flying by this site. Given the lower elevation of this place, Rufous-necked Hornbills were never spotted flying by or stopping in this area.

Discussion

Roost site characteristics

Our study helped us understand the habitats used for roosting by the Great and Wreathed Hornbills. Although our study primarily examined a single roost site each for the Great Hornbill and the Wreathed Hornbill, we also have opportunistically monitored an additional five roosting sites for both species since 2018. Our observations indicate that Wreathed Hornbills prefer riverine habitats, whereas Great Hornbills tend to roost in dense, moist mixed deciduous hill forest patches, often near small water bodies. Naniwadekar *et al*. (2021) also reported similar habitat use patterns, where telemetry was used to understand roost site use in Pakke Tiger Reserve in Arunachal Pradesh, north-east India. The telemetry study of a few tagged Great Hornbill individuals showed that they mainly roost in forests away from rivers during the breeding season. However, in earlier times, between 1997 and 2004 in one site in the Pakke Tiger Reserve, Great Hornbills were seen to use roost sites along the riverbank, sometimes roosting in mixed-species communal roosts along with the Wreathed Hornbill in the non-breeding season (Datta, 2001). Wreathed Hornbills generally prefer to roost in riverine habitats (Datta, 2001, Naniwadekar *et al*., 2021) during breeding and non-breeding seasons. Hornbills usually have no threat from terrestrial predators but can fall prey to arboreal carnivorous mammals such as clouded leopards, binturongs and yellow-throated martens. Studies indicate that nocturnal predators like clouded leopards and binturongs are unlikely to use open riverine habitats (Grassman *et al*., 2005; Tan *et al*., 2017). This could be one reason hornbills select open areas to roost for the night.

Hornbill roost counts and trends

Long-term roosting data can contribute to understanding population dynamics, including trends in population size, spatial and temporal distribution patterns and reproductive success. Our year-long observations of the roost sites in 2022 and 2023 suggest that breeding males and other non-breeding individuals in the population of both species, especially the Wreathed Hornbill tend not to use the same roost site consistently during the breeding season. Wreathed Hornbill numbers at roost sites do not decline much in the breeding season in Arunachal Pradesh. Datta (2001) reported that Great Hornbills roost in the range of 2-9 birds and Wreathed Hornbills in the range of 23-63 in the Pakke Tiger Reserve-Papum Reserve Forest roost site even in the breeding season. Currently, in Pakke Tiger Reserve-Papum Reserve Forest, one roost site is used by Wreathed Hornbills throughout the year, with numbers ranging from around 10 to 109 (data from 2016–2022), while another roost site was only used for a few months in the non-breeding season from August to October (Pradhan *et al*., 2022). Great Hornbills are rarely seen at these riverbank roost sites; singles or pairs are occasionally observed (A. Datta, pers. obs.).

In the Great hornbill roost site, the highest numbers were seen in the non-breeding season from 2018–2019, subsequently they declined marginally and the numbers have remained consistent in the next four seasons from 2020 to 2023. The noticeable dip in the first season

of monitoring could be because the forest patch where they roost has often been subjected to natural forest fires in dry winters. There is an observed habitat degradation, which might be the reason for the hornbills to abandon the roost site in those years and move to other places. In the case of Wreathed Hornbills, the non-breeding numbers have increased from 2019 to 2019–2020, decreasing drastically in 2020-2021 and again increasing in 2021–2022 and 2022–2023 (monitoring in 2023 is still ongoing). In February 2020, we recorded the highest number (224 Wreathed Hornbills) roosting at this site in one single evening, but the highest in 2021 non-breeding season was only 17 birds on one day in February. The reasons for the annual fluctuations in numbers are unclear. The change in numbers at a particular roost site may indicate that hornbills have moved to other roosting sites in some years in response to changing food availability/disturbances; future studies could investigate the possible factors affecting the variation in hornbill numbers using roost sites. Another factor to consider is that there could be undiscovered roosting locations, and some roosts might even be outside the park area. Furthermore, it is important to note that we could not simultaneously monitor hornbills at all known roost sites in a single day. Understanding why hornbill numbers fluctuate at roost sites would require a better understanding of the spatio-temporal distribution of food resources and disturbance factors, simultaneous monitoring of all roost sites, and tracking tagged birds using telemetry.

There is a documented propensity of communal roosting by some hornbill species globally, especially observed in *Rhyticeros* species such as the Wreathed hornbill and the Plain-pouched hornbill (Datta, 2001; Ho and Supari, 2000; Kitamura *et al.*, 2008; Kaur *et al.*, 2011). The Great Hornbills are also reported to roost in relatively large numbers (Kemp and Boesman, 2020) in some sites in Thailand (Pilai Poonswad, pers. comm.) and southern India (Divya Mudappa, pers. comm.). The abundance of Great Hornbills in BTR is estimated to be 161 birds (mean), which is quite low (Pradhan *et al.*, 2024). The numbers seen at roost sites may also indicate their overall abundance at a particular site. The more abundant species are likely to flock in greater numbers. Our population estimates of Wreathed Hornbill populations through transect surveys in BTR indicate that the Wreathed Hornbill has a mean abundance of 375 birds (range 128 to 1104) (Pradhan *et al.*, 2024) which is very close to the total maximum numbers (224) seen at the main river roost site on one day, which points to the possibility that almost the entire population of Wreathed Hornbills could potentially flock together at certain times in one roost site.

Hornbills nest in tree cavities, with nesting males making repeated visits to the nest site to feed the females and chicks during the breeding season (Kemp, 1995). Since hornbills are primarily frugivorous, and their main diet is patchily distributed within a forest (Naniwadekar *et al.*, 2015), the selection and use of roost sites may be influenced by both the nesting sites during the breeding season and the location of foraging areas. However, using telemetry data, Naniwadekar *et al.*, 2021 found that nest or foraging sites did not influence roost selection. Simultaneous monitoring of more roost sites and tracking tagged individuals using telemetry would be needed to understand the movement patterns between different roost sites within the landscape.

Another plausible explanation for the tendency of Wreathed Hornbills to form large roosting flocks during the non-breeding season could be related to food-finding and gathering in-

formation on food resources. The Wreathed Hornbill's diet includes a diversity of non-fig fruit species that are patchily distributed (Datta, 2001; Naniwadekar *et al.*, 2015). In addition, there is a lean period in fruit availability in the low-elevation forests in the non-breeding season (winter months) (Datta, 2001; Datta and Rawat, 2003). In contrast, Great Hornbills rely more on aseasonal fig fruit crops and animal matter (Datta and Rawat, 2003), which are available throughout the year. They are also less wide-ranging and appear to be territorial during the breeding season with small ranges (Naniwadekar *et al.*, 2019). Consequently, Great Hornbills may not need to roost in large communal flocks.

Patterns in roost arrival times

During the non-breeding season, our observations of arrival times indicate that Great Hornbills typically arrive in a short window of time, either at sunset or shortly after. Conversely, flocks of Wreathed Hornbills exhibit a more prolonged arrival period, beginning approximately 38 minutes before sunset. This is possibly because the Great Hornbill may be more susceptible to human disturbances and past hunting pressures. Similar arrival patterns were also seen at roost sites in Pakke TR, where the Great Hornbills arrived at the roost site over a short period during or after sunset (Datta, 2001).

Determining the locations where endangered species like hornbills choose to roost and monitoring the use of these sites is important in identifying critical sites for conservation action or management efforts. Continuous monitoring of roost sites over extended periods can reveal seasonal patterns and trends, possible changes and shifts in population status, but also be indicative of the changing patterns in the use of roost sites. Apart from scientific knowledge, long-term monitoring will aid in detecting potential threats and disturbances and help determine if any environmental changes or anthropogenic pressure impacts the use of these sites. This knowledge is necessary for conservation measures to protect these critical habitats. The long-term protection of these habitats will require working with the local forest department and local communities to safeguard the roosting habitats from tree felling and other disturbances and possibly encouraging the planting of roost tree species in suitable habitats.

Acknowledgements

We are grateful to the West Bengal Forest Department for their cooperation and support throughout the years. We are thankful to several former Principal Chief Conservator of Forests (PCCFs) and Chief Wildlife Warden (CWLWs), Dr. Pradip Vyas, Ravi Kant Sinha and Dr. Debal Ray for granting permission and for their continuous support towards the project's activities. We thank Ujjal Ghosh, Subhankar Sengupta, Kalyan Rai, NS Murali, Buddharaj Sewa, Apurba Sen, Parveen Kaswan, Harish, Jiju Jaesper, B. Siddhartha for their support and help throughout this study. We thank Dr Rohit Naniwadekar for his guidance and inputs to the hornbill project. We thank Rishin Basu Roy, Devsena Roychaudhury and Shreya Das of Nature Mates Nature Club for their continuous support to the field team. This project has been supported by the Whitley-Segré Conservation Fund (till 2020), Stop Poaching Fund, and The Serenity Trust.

Author contributions

AD conceived the study and obtained the funding; ABR obtained the permits and provided logistic and other support; AS, DG, S Mahato, KD, KP, S Mandal

collected the field data with AD occasionally present; DG, KP, S Mandal, AS entered and summarised the data during different time periods, S Mandal and AD analysed the data for this paper with inputs from KP. S Mandal and AD wrote the paper with inputs from KP. All authors read and approved the final manuscript. We thank two anonymous reviewers for their comments.

References

Bhaskar JV and Rai K. 2016. Tiger Conservation Plan (2015–2024) - Buxa Tiger Reserve. Government of West Bengal. 486 pp.

BirdLife International. 2023. Important Bird Area factsheet: Buxa Tiger Reserve (National Park).

Bock A, Naef-Daenzer B, *et al*. 2013. Roost site selection by Little Owls *Athene noctua* in relation to environmental conditions and life-history stages. *Ibis* 155: 847–856.

Canals M, Rosenmann M, and Bozinovic F. 1989. Energetics and geometry of huddling in small mammals. *Journal of Theoretical Biology* 141(2): 181–189.

Canals M, Rosenmann M, and Bozinovic F. 1998. Modulating factors of the energetic effectiveness of huddling in small mammals. *Acta Theriologica* 43 (4): 337–348.

Das 2005. Growth of ethnic groups in forest villages of Buxa Tiger Reserve, West Bengal. *The Indian Forester* 131: 504–517.

Datta A. 2001. A*n ecological study of sympatric hornbills and fruiting patterns in a tropical forest in Arunachal Pradesh*. PhD Dissertation submitted to Saurashtra University, Gujarat, India. 245 pp.

Datta A and Rawat GS. 2003. Foraging patterns of sympatric hornbills in the non-breeding season in Arunachal Pradesh, north-east India. *Biotropica* 35 (2): 208–218.

Datta A and Rane A. 2011. Long-term hornbill nest and roost monitoring in Pakke Wildlife Sanctuary & Tiger Reserve (2003–2010). Report submitted to the Arunachal Pradesh Forest Department, November 2011. 34 pp.

Ganguly D, Mahato S, *et al*. 2022. Study of hornbills in the forests of Himalayan foothills of West Bengal with emphasis on their foraging habit, mate selection and breeding preferences. Interim Report submitted to West Bengal Forest Department. 44 pp.

Gilbert C, McCafferty D, *et al*. 2010. One for all and all for one: the energetic benefits of huddling in endotherms. *Biological Reviews* 85: 545–569.

Grassman LI, Tewes ME, *et al*. 2005. Ranging, habitat use and activity patterns of binturong *Arctictis binturong* and yellow-throated marten *Martes flavigula* in north-central Thailand. *Wildlife Biology* 11(1), 49–57.

Ho HC and Supari S. 2000. Observations of the Plain-pouched Hornbills *Aceros subruficollis* in Tasek Temengor, peninsular Malaysia. *Forktail* 16: 65–67.

Johnston-González R and Abril E. 2019. Predation risk and resource availability explain roost locations of Whimbrel *Numenius phaeopus* in a tropical mangrove delta. *Ibis* 161: 839–853.

Kaur R, Ong T, *et al*. 2011. A survey on mass movements of the vulnerable plain-pouched hornbill in the Belum-Temengor forest complex, peninsular Malaysia. *The Raffles Bulletin of Zoology* 24: 171–176.

Kemp A. 1995. T*he Hornbills*. Oxford University Press. 302 pp.

Kemp AC and Boesman PFD. 2020. Great Hornbill (*Buceros bicornis*), version 1.0. In *Birds of the World* (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.grehor1.01

Kitamura S, Yumoto T, Noma N *et al*. 2008. Aggregated seed dispersal by Wreathed hornbills at a roost site in a moist evergreen forest of Thailand. *Ecological Research* 23: 943–952.

Naniwadekar R, Mishra C, and Datta A. 2015. Fruit resource tracking by hornbills at multiple scales in a tropical forest in India. Journal of *Tropical Ecology* 31:477–490 DOI: http://dx.doi.org/10.1017/S0266467415000449

Naniwadekar R, Rathore A, *et al*. 2019. How far do Asian hornbills disperse seeds? *Acta Oecologica* 101 (2019) 103482. https://doi.org/10.1016/j.actao.2019.103482

Naniwadekar R., Rathore A., *et al*. 2021. Roost site use by Great (*Buceros bicornis*) and Wreathed (*Rhyticeros undulatus*) Hornbill and its implications for seed dispersal. *Biotropica* https://doi.org/10.1111/btp.13039.

Parker PG, Waite TA, and Decker MD. 1995. Kinship and association in communally roosting black vultures. *Animal Behaviour* 49: 395–401.

Peters KA and Otis DL. 2007. Shorebird roost-site selection at two temporal scales: is human disturbance a factor? *Journal of Applied Ecology* 44: 196–209.

Poonswad P, Kemp A, and Strange M. 2013. *Hornbills of the World: a photographic guide*. Draco Publishing. 212 pp.

Pradhan K, Datta, A, *et al*. 2024. Hornbill abundance and habitat relationships in a human-impacted Protected Area in the Indian Eastern Himalaya. *Global Ecology and Conservation* 51 e02868. https://doi.org/10.1016/j.gecco.2024.e02868

Pradhan K, Tachang T, *et al*. 2022. Hornbill Nest Adoption Program (HNAP) Annual Report. 23 pp.

Pradhan K, Mandal S, *et al*. 2023. Study of hornbills in the forests of Himalayan foothills of West Bengal with emphasis on their foraging habit, mate selection and breeding preferences. Interim Report submitted to West Bengal Forest Department. 51 pp.

Rabenold PP. 1986. Recruitment to food in Black Vultures: evidence for following from communal roosts. *Animal Behaviour* 35 (6): 1775–1785.

Rodgers WA and Panwar HS. 1988. Planning a wildlife protected area network in India. 2 vols. Project FO: IND/82/003. FAO, Dehra Dun. 339, 267 pp.

Rohner C, Krebs CJ, *et al*. 2000. Roost site selection of Great Horned Owls in relation to black fly activity: an anti-parasite behavior? *The Condor* 102: 950–955.

Tan CKW, Rocha DG, *et al*. 2017. Habitat use and predicted range for the mainland clouded leopard *Neofelis nebulosa* in Peninsular Malaysia. *Biological Conservation*, 206: 65–74.

Ward P and Zahavi W. 1973. The importance of certain assemblages of birds as 'information centres' for food finding. *Ibis* 115: 517–534.

Weatherhead PJ. 1983. Two principal strategies in avian communal roosts. *The American Naturalist* 121: 237–243.

Zoghby BA, Little RM, *et al*. 2016. Patterns of roost site selection and use by Southern Ground-Hornbills in north-eastern South Africa. *Ostrich* 87: 125–130.

Table S1. Roost site characteristics of a Great hornbill and a Wreathed hornbill roost site in Buxa Tiger Reserve, West Bengal.

Roost site location	Hornbill species	Altitude range (m)	Habitat type	Mean GBH of roost trees (cm)	Mean height of roost trees (m)	Distance to village (km)	Distance to stream/river (m)
Pukhri-Tashigaon	Great hornbill	242-335	Mixed deciduous hill forest	203 (SE ± 21.74)	27 (SE ±1.19)	4	300
Bala river bank	Wreathed hornbill	68-70	Riverine	429 (SE ±134.6)	34 (SE ±2.22)	4	Roost site is located on the river bank

Shilpita Mandal

Dollar Ganguly

Karishma Pradhan

Sitaram Mahato

Kezajacho Dukpa

Arkajyoti Shome

Arjan Basu Roy

Aparajita Datta

Characteristics of hornbill nests in West Kalimantan, Indonesia

Mikael Reporманto[1,2,*], Riyandi[1], and Yokyok Hadiprakarsa[2]

[1] *Department of Biology, Faculty of Mathematics and Natural Sciences, Tanjungpura University, Pontianak, Indonesia*

[2] *Rekam Nusantara Foundation, Rangkong Indonesia, Bogor, West Java, Indonesia.*

***Corresponding author:** Mikael Reporманto (mikael@rekam.or.id)*

Abstract

Hornbills are secondary cavity nesters that rely on naturally formed tree cavities to nest in. However, the nest availability is limited and can easily decline due to habitat degradation. This study describes the characteristics of trees and nest cavities used by four sympatric hornbill species in Kapuas Hulu, West Kalimantan. We used photographic measurements to estimate the nest entrance dimensions, and we also measured nest characteristics such as nest orientation, tree diameter, nest cavity height, nest position on the tree and cavity shapes. We found 18 nest cavities in use—one each by Bushy-crested and Rhinoceros Hornbills, four Wreathed Hornbill nests and 12 used by Black Hornbills. Trees belonging to the Dipterocarpaceae family were mainly used for nesting (83.3%) with an average diameter at breast height of 91.6 cm, an average tree height of 36 m, and a branch-free height of at least 8 m. Most nest cavities were located on the main trunk and had an elongated slit-shaped entrance, with dimensions ranging from 53.6 – 615.2 cm². The nest cavity height ranged from 2.8 – 29.1 m, and the orientation of the nest entrance varied from 62 – 346°, with Wreathed Hornbill nests being relatively more oriented to the east. Additionally, we found that the area of the nest cavity entrance increases with the weight of the hornbill. These findings provide valuable insights into the selection criteria of hornbills for nesting sites in the region, which can help inform conservation efforts to protect these unique birds and their habitats.

Keywords: Borneo, cavity nesting, *Anorrhinus galeritus*, *Anthracoceros malayanus*, *Buceros rhinoceros*, *Rhyticeros undulatus*

Introduction

There are eight species of hornbills in West Kalimantan out of 13 hornbill species found in Indonesia (Hadiprakarsa *et al*., 2020a). All hornbills in West Kalimantan are protected by the Regulation of the Ministry of Environment and Forestry of the Republic of Indonesia (Kementerian Lingkungan Hidup Dan Kehutanan Republik Indonesia, 2018). The Helmeted Hornbill is classified as Critically Endangered (CR), while the Black Hornbill, Rhinoceros Hornbill, and Wreathed Hornbill are classified as Vulnerable (VU), and the Oriental Pied Hornbill is classified as Least Concern (LC) (IUCN, 2020). Several of these hornbill species are listed in CITES (Convention on International Trade in Endangered Species; CITES, 2022). The Helmeted Hornbill is listed in Appendix I, whereas the Black Hornbill, Rhinoceros Hornbill, Wreathed Hornbill,

and Oriental Pied Hornbill are listed in Appendix II (CITES, 2022).

Hornbills nest in naturally formed tree cavities. Natural tree cavities are formed through weathering and animal interventions (Poonswad *et al.*, 2013b). Large trees are often required for nesting which may have a very limited number of suitable cavities, and hornbills also cannot make their own nest cavity, therefore the level of competition is quite high (Poonswad *et al.*, 2013b). Inter-specific competition among hornbills for using nest cavities was 40%, with 78 conflicts occurring during the breeding season (Poonswad *et al.*, 2005). Damaged nests are also a factor in reducing the availability of suitable nesting cavities for breeding. Twenty six percent of the 106 nests that were occupied by hornbills had to be repaired in an earlier study (Poonswad *et al.*, 2005).

Several species of hornbills also have specific requirements in selecting nesting cavities (Sibarani *et al.*, 2020). The more hornbill species there are, the more varied the characteristics of nest selection become. Describing nest characteristics in locations with multiple species can help fill the knowledge gap on the specific nesting preferences of each species (Poonswad, 1995; Mudappa and Kannan, 1997; Datta and Rawat, 2004; Naniwadekar *et al.*, 2020). The availability of nesting cavities is a factor that influences hornbill populations (Utoyo *et al.*, 2017). Therefore, it is necessary to document and understand the characteristics of nest trees and the dimensions of the cavities used by different species of hornbills that occur sympatrically. In addition, while there have been several studies of hornbill nest site characteristics from South Asia and other parts of Southeast Asia, this is the first study that quantitatively describes nest site characteristics of several species of hornbills from Indonesia.

Methods

This research was conducted in the forests of Batu Lintang village. The data collection area included swamp heath forests, secondary forests, and lowland dipterocarp forests. Batu Lintang village is in Embaloh Hulu District, Kapuas Hulu Regency, West Kalimantan, Indonesia. Batu Lintang village (Fig. 1) has an area of 17,772 ha consisting of Pulan settlement covering 8,292 ha and Sungai Utik settlement which is a Customary Forest with an area of 9,480 ha (Kementrian Lingkungan Hidup Dan Kehutanan Republik Indonesia, 2020).

This research was conducted from February to March 2022 during the non-breeding period. Nest location data was collected through community interviews and Rangkong Indonesia's existing data. Data by the Rangkong Indonesia team was obtained through reports

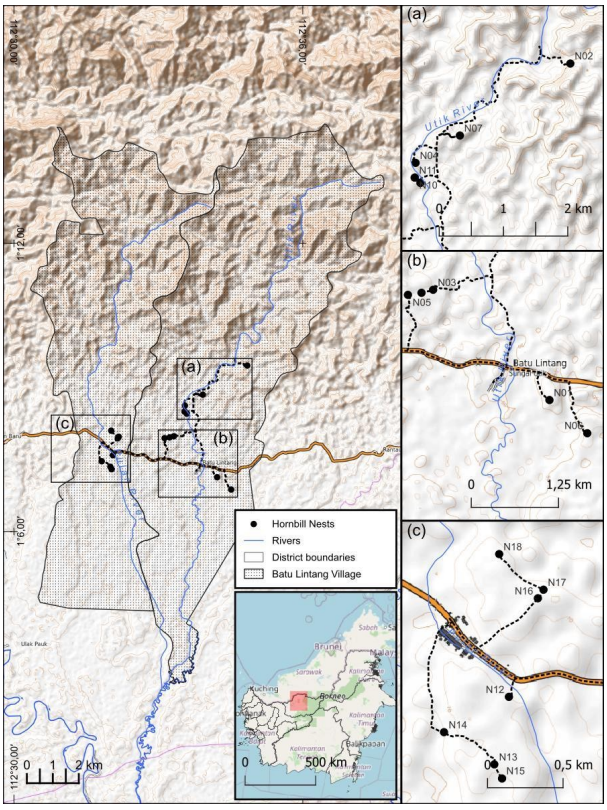

Fig. 1. Map of the study area in West Kalimantan, Indonesia.

from residents regarding the presence of nests, which were then confirmed in the field. This data remains opportunistic due to the unstructured and non-representative nature of the surveys, as nest data is limited to areas frequently visited by the community. Interviews were conducted with community members actively engaged in forest activities to gather information about hornbill activity and potential tree cavities for nests. After collecting information, community members were invited to confirm the tree cavities and profile the nest trees. Potential nest tree cavities were identified by food plant seedlings on the ground, smooth nest entrances, and signs of nest seals at the entrance. Nests were categorised as active when they have the potential to be occupied again by hornbills; inactive nests are those whose conditions do not allow them to be reused.

The tools we used to mark the nest trees included a GPS (Global Positioning System) handset to record location, a Phi-band or tape measure to measure DBH (diameter at breast height), and a compass to determine the orientation of the cavity entrance. Tree height was measured using a rangefinder Bushnell Trophy Xtreme, standing at the base of the tree and measuring to the top of the tree canopy, the height of the first branch was measured by aiming the rangefinder to the junction of the lowest branch attachment to the main trunk, and the nest height from the ground was measured by aiming the rangefinder to the lower edge of the nest entrance. We measured both the active nest trees that have been used by four out of the eight sympatric hornbill species for nesting and/or the inactive nests which have the potential to be reoccupied. The four focal hornbill species were the Bushy-crested Hornbill *Anorrhinus galeritus* (body weight: 933 – 1247 g; body length: 60 – 90 cm), Black Hornbill *Anthracoceros malayanus* (633 – 1050 g; 60 – 80 cm), Wreathed Hornbill *Rhyticeros undulatus* (2685 – 3650 g; 100 – 117 cm) and Rhinoceros Hornbill *Buceros rhinoceros* (2330 – 3000 g; 79 – 90 cm).

We measured the tree characteristics and the cavity dimensions (Table 1). Estimates of the height and width of the nest entrance were calculated using the formula from Fulton (2020) with several adaptations of the Poonswad (1995) formula by adjusting the type of camera (canon 1200d), sensor size, lens focal length, and distance between the camera and the nest cavity. The modification was considered given the existence of new tools such as rangefinders and DSLR cameras. Measurement of 35 mm film rolls and objects on film in mm units in the Poonswad (1995) formula was replaced by camera sensor sizes and objects in mm and pixels with the Image J 1.53f application (Fig. 2).

$$\textbf{Object height on sensor (mm)} = \frac{B'(\text{mm}) \times L'(\text{pixels})}{B'(\text{pixels})}$$

$$\textbf{Object width on sensor (mm)} = \frac{C'(\text{mm}) \times W'(\text{pixels})}{C'(\text{pixels})}$$

$$\mathbf{L} = \frac{D' \times \text{Object height on sensor (mm)}}{FL}$$

$$\mathbf{W} = \frac{D' \times \text{Object width on sensor (mm)}}{FL}$$

(formula modification Fulton, 2020)

$$\mathbf{EL1} = L - l$$

$$\mathbf{EL2} = (L - l)/L$$

$$\mathbf{EW1} = W - w$$

$$\mathbf{EW2} = (W - w)/W$$

Notation: L = Real Object height (cm), l = Scaled nest entrance height photo (cm), W = Real object width (cm), w = Scaled nest entrance width photo (cm), C' = Sensor width, B' = Sensor height, L' = Object height (pixel), W' = Object width (pixel), D' = Distance to object (cm), FL = Focal Length (mm).

The nest entrance error formula is the difference between the estimated nest entrance measurement using the formula and the measurement using a scale photograph. EL1 = Error calculating the height of the entrance to the nest (cm), EL2 = Error calculating the height of the entrance to the nest (%), EW1 = Error calculating the width of the entrance to the nest (cm), EW2 = Error calculating the width of the entrance to the nest (%). All data were compiled and analysed using Microsoft Excel. The data were analysed descriptively, by comparing results in this study with the others.

Table 1. Data variables measured at the nest tree.

Variable	Description
Nest Tree	
Tree species	The species of nest tree[a]
Diameter at breast height (cm)	Measurement of diameter at breast height of tree nests[a]
Tree height (m)	Measured from ground level[a]
Nest cavity height (m)	Measured from ground level[a]
Height of first branch (m)	Measured from ground level[a]
Nest entrance	
Nest entrance width (cm)	Measurement estimation by photographs[b]
Nest entrance height (cm)	Measurement estimation by photographs[b]
Nest entrance area(cm^2)	width x height[a]
Nesting Cavity Parameters	
Nest entrance orientation (°)	Directly measured[d]
Nest shape	Round is the ratio of the width and height of the nest entrance <1/2, Oval is the ratio of the width and height of the nest entrance = 1/2, Slit is the ratio of the width and height of the nest entrance > 1/2[c]
Nest entrance position	Main Trunk, Primary, Secondary or Tertiary Branch[e]

[a] Rahayuningsih et al. (2017), [b] Poonswad (1995), [c] Poonswad (2012), [d] Sibarani et al. (2020), [e] Datta and Rawat (2004).

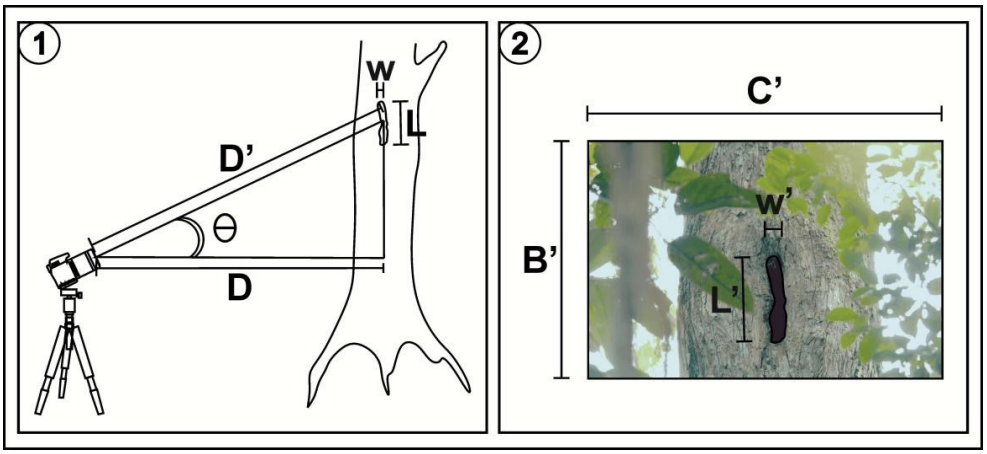

Fig. 2. Method of measuring the nest cavity entrance based on modification of Poonswad, 1995 and Fulton, 2020.

Results

A total of 18 hornbill nests was measured, consisting of nine active and three inactive Black Hornbill nests, one active Bushy-crested Hornbill nest, one active Rhinoceros Hornbill nest, and four active Wreathed Hornbill nests. There were 14 tree species utilised by four species of hornbills for nesting, primarily from the Dipterocarpaceae family (83.33%) (*Rubroshorea macrophylla* (de Vriese) P. S. Ashton & J. Heck, *R. retusa* (Meijer) P. S. Ashton & J. Heck, *Shorea* sp. 1 (red meranti), *R. albida* (Symington) P. S. Ashton & J. Heck, *Shorea* sp. 2 (red meranti), *Shorea* sp. 3 (red meranti), S*horea* sp. 4 (red meranti), *S. pachyphylla* Ridl. Ex Symington, R. *parvifolia* (Dyer) P. S. Ashton & J. Heck, *Dipterocarpus crinitus* Dyer, *Dipterocarpus* sp.) and the remaining were from Burseraceae (*Dacryodes* sp.), Clusiaceae (*Garcinia mangostana* L), Crypteroniaceae (*Dactylocladus stenostachys* Oliv). Meranti (*R. albida)* is a frequently used tree species for nesting, accounting for 16.7% of recorded nest trees. All the nest trees were found in lowland forests at elevations ranging from 18 to 126 m asl (Table 2).

Bushy-crested Hornbill nests were on trees with the largest diameter at breast height (DBH) of 130 cm, while the Black Hornbill utilised trees with the smallest DBH of 78.8 cm. The nest tree height for each hornbill species varied between 32.5 and 44.9 m. The height of the first branch of the nest tree ranged from 19.6 to 31.2 m. The distance between the nest entrance and the first branch ranged from 80 – 100.9 cm. The shortest distance was 80 cm for the Wreathed Hornbill, while the longest is 100.9 cm for the Black Hornbill (Table 3).

The highest nest entrance from the ground was 28.5 m for the Bushy-crested Hornbill, while the lowest was 8.8 m for the Black Hornbill (Table 4). The large hornbill (Rhinoceros Hornbill) had the tallest, widest, and largest nest entrance. Conversely, the small hornbill (Bushy-crested Hornbill) had the lowest nest entrance height, while the Black Hornbill had the smallest nest entrance width (Table 4). The error of the nest entrance height was 0.56 cm (-3.86%), while the width error was -1.11 cm (-25.38%) (Table 4). Large hornbills have the largest nest entrance area, whereas small hornbills have the smallest area (Table 4).

Eighteen nest cavities from seventeen nest trees of four hornbill species were characterised. The Black Hornbill nests consisted of active nests (N01 – N05, N07, N09, N11, N12) and inactive nests (N06, N08, N10). The active nest of the Bushy-crested Hornbill was N13, while the active nests of the Wreathed Hornbill were N14 – N17, and the active nest of the Rhinoceros Hornbill was N18. The inactive

Table 2. Species and proportions of hornbill nest trees.

No.	Hornbill Species	Nest Tree Family			
		Dipterocarpaceae	Burseraceae	Clusiaceae	Crypteroniaceae
1	Black Hornbill	9	1	1	1
2	Bushy-crested Hornbill	1	n/a	n/a	n/a
3	Wreathed Hornbill	4	n/a	n/a	n/a
4	Rhinoceros Hornbill	1	n/a	n/a	n/a
Total nest trees		15	1	1	1

Table 3. Characteristics of hornbill nest trees.

Variables (Mean ± SD)	Hornbill Species			
	BH	BCH	WH	RH
Diameter at breast height (cm)	(78.8 ± 27.6)	(130 ± 0)	(125 ± 12.8)	(73.2 ± 0)
Tree height (m)	(32.5 ± 6.9)	(44.9 ± 0)	(42.7 ± 3.6)	(41.6 ± 0)
Height of first branch (m)	(19.6 ± 5.8)	(31.2 ± 0)	(24.8 ± 5.5)	(26.6 ± 0)

BH – Black Hornbill, BCH – Bushy-crested Hornbill, WH – Wreathed Hornbill, RH – Rhinoceros Hornbill.

Black Hornbill nest N06 had been taken over by stingless bees (Figure 3). Nest N08 was overgrown with moss and along with N07, constituted two cavities in the same tree. Nests N10, N11, and N12 were located on the edge of hunting trails, and according to local accounts, the parent hornbill at nest N10 was shot by hunters, rendering it unused. In addition to human disturbances, some nests also suffered damage, such as nest N10, which was flooded (Figure 3).

The nest entrance direction of the Black Hornbill ranged from northwest to northeast (Table 5). The nest entrances of Bushy-crested and Rhinoceros Hornbill were oriented between southeast and east-southeast. The Wreathed Hornbill occupies nest cavities oriented relatively more towards the east (Table 5).

Table 4. Characteristics of hornbill nest cavities.

Variables	Hornbill Species			
	BH [a]	BCH [a]	WH [a]	RH [a]
Nest entrance height (cm)	(28.5± 8.9)	(17.1 ± 0)	(28.8 ± 15.3)	(58.3 ± 0)
Error (cm)[b]	(0.56 ± 8.03)			
Error (%)[b]	(-3.86 ± 0.29)			
Nest entrance width (cm)	(6.4 ± 2.2)	(10.4 ± 0)	(9.2 ± 5.4)	(10.6 ± 0)
Error (cm)[c]	(-1.11 ± 0.97)			
Error (%)[c]	(-25.38 ± 0.20)			
Nest entrance area (cm^2)	(175 ± 49.6)	(178.9 ± 0)	(237.9 ± 140.3)	(615.2 ± 0)
Nest cavity height (m)	(8.8 ± 5.1)	(28.5 ± 0)	(24 ± 7.6)	(15.8 ± 0)
Nest entrance orientation (°)	(188.3 ± 89.1)	(120 ± 0)	(98.8 ± 14.8)	(129 ± 0)

BH – Black Hornbill, BCH – Bushy-crested Hornbill, WH – Wreathed Hornbill, RH – Rhinoceros Hornbill, [a] Mean±SD, [b] Error for all nest entrance heights, [c] Error for all nest entrance widths.

Table 5. Qualitative characteristics of hornbill nest trees.

Parameters	Black Hornbill	Bushy-crested Hornbill	Wreathed Hornbill	Rhinoceros Hornbill
Nest status	Active (9) Inactive (3)	Active (1)	Active (4)	Active (1)
Nest entrance position	Main Trunk (12)	Main Trunk (1)	Primary (1)	Main Trunk (1)
Nest shape	Slit (11)	Round (1)	Slit (3)	Slit (1)
Nest cavity direction	Northwest to Northeast	Southeast	East	East-southeast

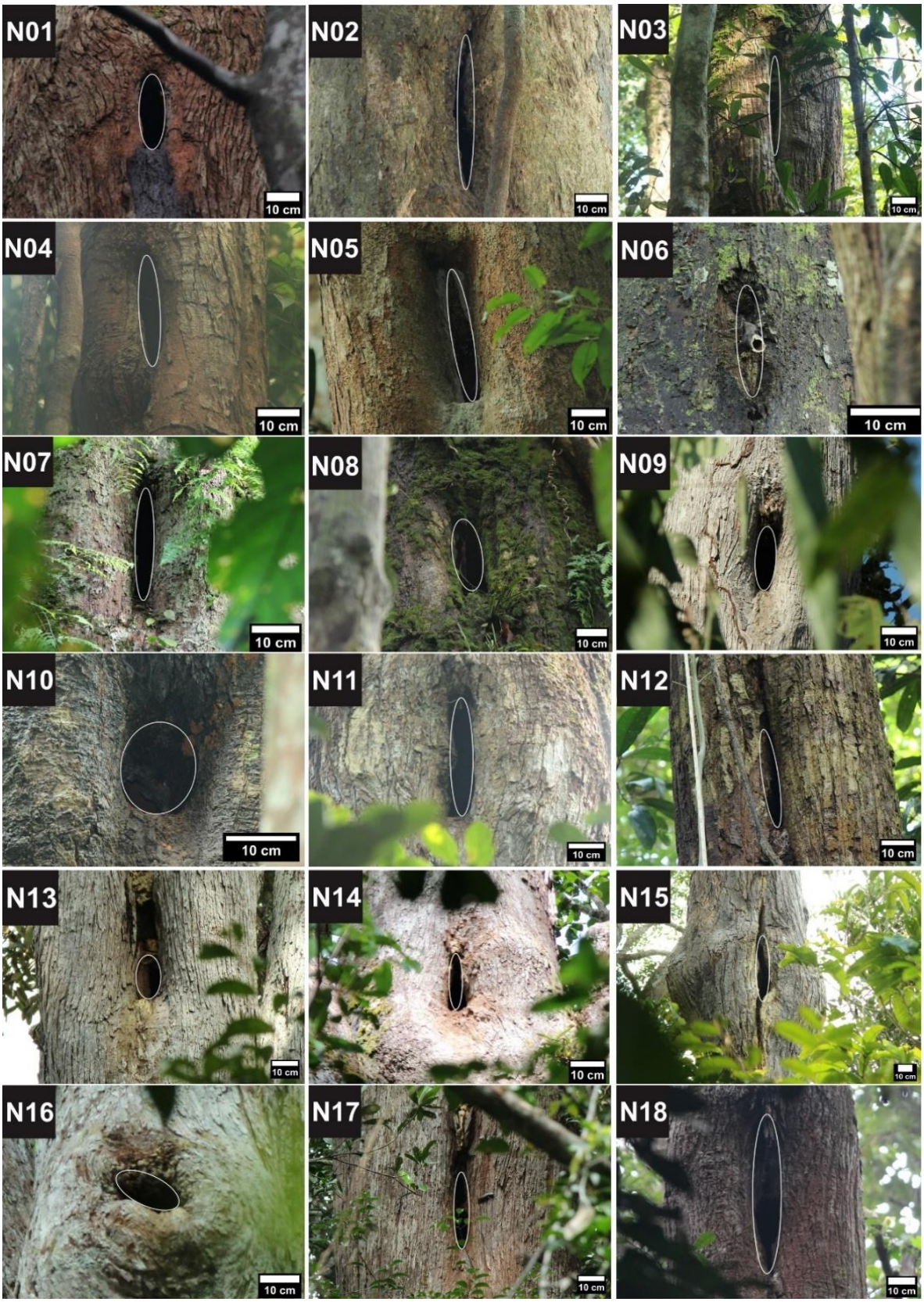

Fig. 3. Hornbill nest cavities recorded in Kapuas Hulu, 2022. Nest cavities of Black Hornbill (N01 – N12), Bushy-crested Hornbill (N13), Wreathed Hornbill (N14 – N17), and Rhinoceros Hornbill (N18). Photo: Mikael Repormanto.

Discussion

Four species of hornbills (Rhinoceros Hornbill, Wreathed Hornbill, Bushy-crested Hornbill, and Black Hornbill) were found nesting out of the eight hornbill species present in West Kalimantan. The species whose nests have not been found are the White-crowned Hornbill, Helmeted Hornbill, Wrinkled Hornbill, and the Oriental Pied-Hornbill. A population survey by Hadiprakarsa *et al*. (2020b) showed that all eight hornbill species were found at the study site. It is possible that the nests of the other four species (White-crowned Hornbill, Helmeted Hornbill, Wrinkled Hornbill, and Oriental Pied Hornbill) have not been found due to opportunistic nest data collection based solely on community reports. Nest exploration was limited to areas frequently visited by the local community. Additionally, the habitats of these four species are relatively far from human settlements, and sightings were rare in the study area (Hadiprakarsa *et al*. 2020a).

The nesting record may indicate which hornbill species are more common in the study area. In this study, we recorded more Black Hornbill nests (66.7%), indicating that this species is the commonest in the study area, followed by Wreathed Hornbill (22.2%). This is an interesting finding because nests of Black Hornbill are quite rare in some areas of the species range, as shown by several past studies (Poonswad, 1995; Sibarani *et al*. 2020). The Black Hornbill and Wreathed Hornbill are commonly found in lowland forests ranging from below 200 m asl (Hadiprakarsa *et al*., 2020a), as shown by this study.

Black Hornbill is believed to have a relatively high tolerance for environmental changes like its close relative, the Oriental Pied Hornbill, which is also found near settlements and secondary forests affected by logging (Hadiprakarsa *et al*., 2020a; BirdLife International, 2022). However, this species is locally common and higher numbers of nest trees were found for this species. Most Black Hornbill nest trees are in swampy heath (Kerapah) forest areas with litter-rich, occasionally flooded, and sandy soil. Black Hornbill nest trees in flat lowland areas (<100 m asl) typical of swampy heath forests are also found in selectively logged secondary forest areas. This aligns with the findings of previous studies (McConkey and Chivers, 2004; Lubis *et al*., 2023; Ridho *et al*., 2023). Black Hornbills in Indonesia are also found in the lowland dipterocarp forests, secondary forests, patches of secondary forest, and heath forests (Kerangas). Protecting this area is recommended, as it is in a non-conservation area, and hunting and habitat degradation are potential threats to the species.
We recorded only a single nest of the Bushy-crested Hornbill and the Rhinoceros Hornbill. The limited number of nests is due to the information being restricted to areas most frequently explored by the community in the swampy heath (*kerapah*) forest, making the data less representative and opportunistic. Exploration of specific habitats, such as lowland dipterocarp forests, is also necessary to ensure appropriate representation.

Almost all tree species used by the four hornbill species were identified as species of the Dipterocarpaceae family. This tree family comprises species with relatively strong and durable wood (Muslich and Sumarni, 2006). For example, Meranti *Shorea* spp. and Keruing *Dipterocarpus* spp. fall into durability classes 1–3 (Muslich and Sumarni, 2006). Almost all these nest trees showed large girth (DBH = 73.2–130 cm). This is in line with previous research that showed that hornbills tend to use trees with DBH more than 40 cm and tree height >35 m (Kinnaird and O'Brien, 2007; Rahayuningsih *et al*., 2017; Poonswad, 1995).

Female Rhinoceros Hornbills use nests with the longest, widest, and largest entrances, although the data may not be fully representative due to

the sample size of only one. This is likely related to their relatively long body and wings, as well as their wide beaks. A relatively high nest entrance is believed to facilitate the movement of the female hornbill when entering or exiting the nest. According to Poonswad *et al*. (2013b), the female hornbill enters or exits the nest by inserting or withdrawing her head first, followed by her wing in a sideways movement. A relatively wide nest entrance makes it easier for the hornbill's beak to enter or exit. The Rhinoceros Hornbill has the largest beak size compared to the other three species (Tobias *et al*., 2022). The nest entrance must be wider than the hornbill's beak. The width of the Rhinoceros hornbill's nest entrance is 10.6 cm (Table 4), which is wider than the average beak width of female Rhinoceros hornbills at 4.96 cm (Tobias *et al*., 2022). The size of the nest cavity greatly corresponds to the size of the hornbill, as hornbills choose nest cavities that are as small as possible to minimise the effort required to seal the entrance (Poonswad, 1995).

The Bushy-crested Hornbill uses nests with the lowest entrance height. This is likely due to the Bushy-crested Hornbill's body and wing size, which are the second smallest after the Black Hornbill (Hadiprakarsa *et al*., 2020a; Tobias *et al*., 2022). However, the sample size for the Bushy-crested Hornbill is only one nest, which is insufficient to fully justify this assumption. The Black Hornbill uses nests with the smallest entrance width. This is consistent with the entrance width of 6.4 cm (Table 4), which is larger than the beak width of 3.15 cm (Tobias *et al*., 2022).

The variation in nest cavity area is related to the hornbill's body size. The relatively large body size of hornbills is a limiting factor in the availability of appropriate cavity sizes . Large hornbills have wider nest entrance openings than smaller hornbills (Table 4). Rhinoceros and Wreathed hornbills are large compared to the Bushy-crested and Black hornbills. Small hornbills are also relatively lighter (Poonswad *et al*. 2013b; Hadiprakarsa *et al*., 2020a).

The lowest nest cavity positions were at Black Hornbill nests. The breeding duration of Black Hornbill is relatively shorter (± 50 days) than Bushy-crested (± 96 days), Wreathed (126 days), and Rhinoceros Hornbill (± 122 days) (Poonswad *et al*. 2013b). A relatively short breeding duration reduces the likelihood of predator threats. Bushy-crested, Wreathed, and Rhinoceros Hornbill being larger in size, have relatively longer breeding durations. Hornbills with a longer breeding duration may require higher nests to reduce the predator threat (Poonswad, 1995).

The orientation of Wreathed Hornbill nest cavities is relatively towards the east. Wreathed Hornbill are believed to prefer cavities with morning light exposure. However, for the Black Hornbill, nest orientation is still random, while there is only one nest each for the Rhinoceros Hornbill and the Bushy-crested Hornbill. Morning light has long wavelengths that can accelerate bird reproductive performance (Yang *et al*., 2016; Rizal, 2018).

Three Black Hornbill nests were inactive. The nest cavities were inactive due to collapsed, flooded, narrowed, or widened nest floors, making them unsuitable for hornbills to nest (Poonswad *et al*., 2005). In addition to structural damage, nests were also taken over by stingless bees, while poaching of hornbill chicks from their nests also affects nest usage (Poonswad, *et al*., 2013a; Vercoe *et al*., 2021). Stingless bees can seal the nest cavities when their colonies occupy tree cavities. This occurs in 91.5% of large trees with a DBH of 60-120 cm, particularly within the Dipterocarpaceae family (Eltz *et al*., 2002; Macedo *et al*., 2020). Hornbill nests are taken over by different species up to 50% of the time, with some of the species that take over the nests including the sun bear, Great

Slaty Woodpecker, Yellow-throated Marten, and monitor lizards (Datta and Rawat, 2004; Poonswad *et al.*, 2005).

Most of the nest cavities were on the main trunk, similar to observations on hornbill nest trees in India (Datta and Rawat, 2004). The formation of cavities in Dipterocarpaceae trees is done by woodpeckers (Kumar e*t al.*, 2011). The cavities formed undergo enlargement and are then occupied by hornbills, which is consistent with Poonswad e*t al.* (2013b) who reported hornbills using nest cavities formed by woodpeckers. In Kalimantan, there are 18 species of woodpeckers and nine species of barbets (Eaton e*t al.*, 2022). Additionally, cavity formation in the main trunk can occur due to stem injuries and decomposition by wood-decaying microorganisms such as *Trichoderma* sp., *Gliocladium* sp., and *Fusarium* sp. (Supa-Amornkul e*t al.*, 2011). Only a small portion of the cavities were located on the primary branches, similar to Datta and Rawat (2004). Cavity formation on branches is due to branch breakage, including injuries caused by wildlife and decaying wood (Poonswad, 1995; Poonswad e*t al.*, 2013b). This study aligns with the findings of Datta and Rawat (2004) in India, where Great Hornbills *Buceros bicornis t*end to choose slit-shaped cavities. The shape of one nest entrance for the Wreathed hornbill is oval (Table 5), which is also consistent with Datta and Rawat (2004). However, the data in this study are limited in explaining the reasons behind the preference for nest shapes, highlighting a research gap that warrants further exploration.

References

BirdLife International. 2022. Species factsheet: *Anthracoceros malayanus*. Retrieved June 20, 2022, from http://datazone.birdlife.org/species/factsheet/black-hornbill-anthracoceros-malayanus/text.

CITES. 2022. Daftar Periska Spesies CITES. Retrieved November 19, 2022, from https://checklist.cites.org/.

Datta A and Rawat GS. 2004. Nest-site selection and nesting success of three hornbill species in Arunachal Pradesh, north-east India: *Buceros bicornis*, *Aceros undulatus* and *Anthracoceros albirostris*. *Bird Conservation International* 14: 39–52. doi:10.1017/S0959270905000213.

Eaton JA, Van Balen B, et al. 2022. *Burung-burung Pulau Paparan Sunda dan Wallacea di Kepualuaan Indonesia*. Lynx Edicions, Barcelona.

Eltz T, Brühl CA, *et al*. 2002. Determinants of stingless bee nest density in lowland dipterocarp forests of Sabah, Malaysia. *Oecologia* 1: 27–34. doi:/10.1007/s00442-001-0848-6.

Fulton W. 2020. Calculate Distance or Size of an Object in a Photo Image. Retrieved October 1, 2021, from https://www.scantips.com/lights/subjectdistance.html.

Hadiprakarsa Y, Rahman A, et al. 2020a. *Enggang Kalimantan: Panduan Praktis Identifikasi Lapangan*. Rangkong Indonesia, Bogor.

Hadiprakarsa Y, Winarni NL *et al*. 2020b. Laporan Survei Populasi dan Okupansi Rangkong di Bentang Alam Kapuas Hulu, Kalimantan Barat. Rangkong Indonesia.

IUCN. 2020. IUCN RED LIST. Retrieved November 19, 2022, from https://www.iucnredlist.org/search/list?query=Buceros%20rhinoceros&searchType=species.

Kementerian Lingkungan Hidup Dan Kehutanan Republik Indonesia. 2018. Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia NomorP.106/Menlhk/Setjen/Kum.1/12/2018 Tentang Perubahan Kedua Atas Peraturan Menteri Lingkungan Hidup Dan Kehutanan Nomor P.20/Menlhk/Setjen/Kum.1/6/2018 Tentang Jenis Tumbuhan Dan Satwa Yang Dilindungi.

Kementrian Lingkungan Hidup Dan Kehutanan Republik Indonesia. 2020. Penetapan Hutan Adat Menua Sungai Utik Kepada Masyarakat

Hukum Adat Dayak Iban Menua Sungai Utik Ketemenggungan Jalai Lintang Seluas 9.480 Hektar. Lokasinya Berada Di Kawasan Hutan Lindung (HL) Seluas 3.862 Hektare, Di Kawasan Hutan Produksi Terbatas (HPT) Seluas 5.518 Hektare, Dan Areal Penggunaan Lain (APL) Seluas 100 Hektare Di Desa Batu Lintang, Kecamatan Embaloh Hulu, Kabupaten Kapuas Hulu, Kalimantan Barat.

Kinnaird MF and O'Brien TG. 2007. *The ecology and conservation of Asian hornbills: farmers of the forest*. University of Chicago Press, Chicago.

Kumar R, Shahabuddin G, *et al*. 2011. How good are managed forests at conserving native woodpecker communities? A study in sub-Himalayan dipterocarp forests of northwest India. *Biological Conservation* 144: 1876–1884. doi:10.1016/j.biocon.2011.04.008.

Lubis MFA, Sawitri HI, *et al*. 2023. Species richness, population, sex ratio and activities of hornbills inhabiting patches of forests in an oil palm plantation concession in Penajam Paser Utara, East Kalimantan. *IOP Conference Series: Earth and Environmental Science*. Juli 1, 2023, Indonesia.

Macedo CRDC, Aquino IDS, *et al*. 2020. Nesting behavior of stingless bees. *Ciência Animal Brasileira* 21. doi:10.1590/1809-6891v21e-58736.

McConkey KR and Chivers DJ. 2004. Low mammal and hornbill abundance in the forests of Barito Ulu, Central Kalimantan, Indonesia. *Oryx* 38: 439–447. doi:10.1017/S0030605304000821.

Mudappa DC and Kannan R. 1997. Nest-site characteristics and nesting success of the Malabar Gray Hornbill in the southern Western Ghats, India. *The Wilson Bulletin* 109: 102–111

Muslich M and Sumarni G. 2006. Durability of 25 Dipterocarpaceae Wood Species Against Marine Borers. *Jurnal Penelitian Hasil Hutan* 24:191–200.

Naniwadekar R, Ghuman S, *et al*. 2020. Characteristics of Narcondam Hornbill *Rhyticeros narcondami* nest trees. *Hornbill Natural History & Conservation* 2: 1–9.

Poonswad P. 1995. Nest site characteristics of four sympatric species of hornbills in Khao Yai National Park, Thailand. *Ibis* 2: 183–191. doi:10.1111/j.1474-919X.1995.tb03238.x.

Poonswad P. 2012. *Hornbills: A Thai Heritage-a World Heritage*. Thailand Hornbill Project: Faculty of Science Mahidol University. Bangkok.

Poonswad P, Chimchome V, et al. 2013a. Conservation of Hornbills in Thailand. In: *Conservation Biology*, N. S. Sodhi, L. Gibson, and P. H. Raven (Eds.). Wiley-Blackwell; 1st edition, USA: 157–166.

Poonswad P, Kemp A, et al. 2013b. *Hornbills of the World: A Photographic Guide*. Draco Publishing & Distribution Pte Ltd. Bangkok.

Poonswad P, Sukkasem C, *et al*. 2005. Comparison of cavity modification and community involvement as strategies for hornbill conservation in Thailand. *Biological Conservation* 3: 385–393. doi:10.1016/j.biocon.2004.08.002.

Rahayuningsih M, Kartijono NE, *et al*. 2017. Short Communication: The nest characteristics of Wreathed Hornbill (*Rhyticeros undulatus*) in Mount Ungaran, Central Java, Indonesia. *Biodiversitas, Journal of Biological Diversity* 18: 3. doi:10.13057/biodiv/d180334.

Ridho D, Marhaento H, *et al*. 2023. The diversity of birds in the young oil palm agroforestry plot in Jambi, Indonesia. *IOP Conference Series: Earth and Environmental Science*. February 1, 2023, Indonesia.

Rizal R. 2018. Mitos dan Eksplanasi Ilmiah Lembayung Senja. *Jurnal Filsafat Indonesia* 1:16. doi:10.23887/jfi.v1i1.13970.

Sibarani MC, Utoyo L, *et al*. 2020. Long-term monitoring of nesting behavior and nesting habitat of four sympatric hornbill species in a Sumatran lowland tropical rainforest of Bukit Barisan Selatan National Park. *Hornbill Natural History Conservation* 1: 17–29.

Supa-Amornkul S, Wiyakrutta S, *et al*. 2011. Wood Decay Fungi In Hornbill Nest Cavities In Khao Yai National Park, Thailand. *The Raffles Bulletin of Zoology* 24: 95–113.

Tobias JA, Sheard C, *et al*. 2022. AVONET:

morphological, ecological and geographical data for all birds. Coulson T, editor. *Ecology Letters* 3: 581–597. doi:/10.1111/ele.13898.

Utoyo L, Marthy W, *et al*. 2017. Nesting cycle and nest tree characteristics of the Helmeted Hornbill *Rhinoplax vigil*, compared to the Wreathed Hornbill *Rhyticeros undulatus*, in Sumatran lowland rainforest. *Kukila* 20: 12–22.

Vercoe M, Barton C, *et al*. 2021. Artificial nest cavities can sustain populations of hornbills in the degraded forests of Kinabatangan, Borneo. *Oryx* 3: 331–331. doi:10.1017/S0030605321000181.

Yang Y-F, Jiang J-S, et al. 2016. The relationship of spectral sensitivity with growth and reproductive response in avian breeders (*Gallus gallus*). *Scientific Reports* 1: 92–91. doi:10.1038/srep19291.

Mikael Repormanto

Riyandi

Yokyok Hadiprakarsa

Observation on an artificial nest of a Sri Lanka Grey Hornbill (*Ocyceros gingalensis*) in an urban setting

Damindu J.C. Wijewardana[1], Iresha I. Wijerathne[2,3], and Sriyani Wickramasinghe[4]

[1] *Faculty of Natural Science, Open University of Sri Lanka, Kandy, Sri Lanka*

[2] *Royal Botanical Gardens, Sri Lanka*

[3] *Guangxi Key Laboratory of Forest Ecology and Conservation, College of Forestry, Guangxi University, Daxuedonglu 100, Nanning 530004, China*

[4] *Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka*

***Corresponding author:** Damindu J. C. Wijewardana (daminduwij@gmail.com)*

Abstract

Ocyceros gingalensis *is a species endemic to Sri Lanka, having a vital ecological role in seed dispersal and maintaining rainforests. However, like many wildlife species, hornbills face threats from deforestation. Hence, introducing artificial nests would be one of the solutions for hornbills to overcome the problem of lack of mature, large trees with suitable cavities. This study was focused on an* Ocyceros gingalensis *nest in an urban setting. Although up until now, the only records of urban nests were of natural cavities, this particular nest was within an aluminum pot. This nest gave insight into how its diet varied compared to wild nests and a feasible alternative to current artificial nests used for conservation.*

Keywords: artificial nesting, feeding patterns, nesting habits, Suburban

Introduction

Sri Lanka is an equatorial island home to two species of hornbills—the Sri Lanka Grey Hornbill (*Ocyceros gingalensis*), which is endemic to the island, and the Malabar Pied Hornbill (*Anthracoceros coronatus*), a South Asia endemic. The Sri Lanka Grey Hornbill has a predominantly grey and white plumage. The male and female can be differentiated by the colour of their beaks. Malabar Pied Hornbill, on the other hand, has black and white feathers, a bright yellow bill and a prominent casque with a large black patch along the upper ridge and whitish throat patches. The male and female possess similar appearances; orbital skin is bluish-black on males and pinkish-white on females (Legge,1880). These birds are captivating and iconic with their striking appearance, unique breeding behaviour and ecological importance. According to Kotagama *et al.* (2011) and Wickramasinghe and Wijerathne (2022), the distribution patterns of the two species change with the disturbances in the ecosystems.

These birds are predominantly frugivorous, feeding on various fruits found in the dense rainforests (Kemp, 1995). They, hence, play a crucial role in seed dispersal, aiding in the regeneration and growth of forest ecosystems (Wijerathne *et al.*,

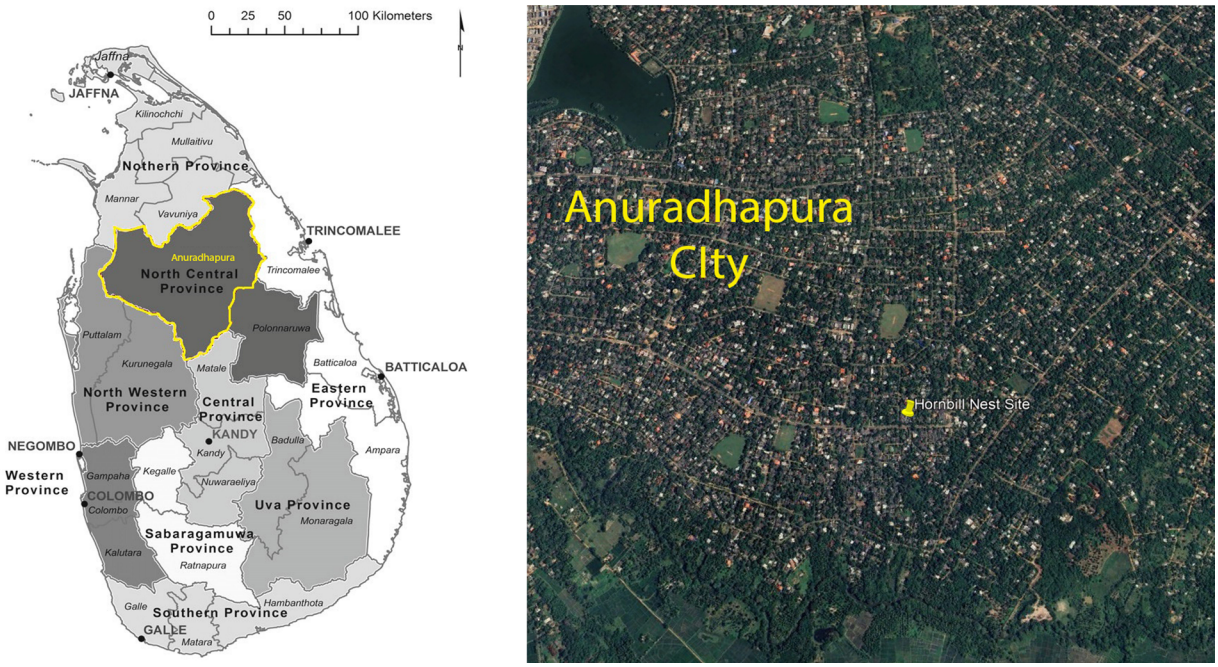

Fig. 1. Study site near the town of Anuradhapura, North Central Province, Sri Lanka.

2023). The female seals herself within a tree cavity using a mixture of mud and droppings, leaving only a narrow slit for the male to pass food to her and their chicks (Wijerathne and Wickramasinghe, 2018; 2019). This unique nesting strategy of hornbills ensures greater safety and survival of the chicks and females by providing protection. The feeding patterns also change during this period as their diet includes insects, small reptiles, birds, and whole snails in addition to figs to fulfill the protein requirement of the growing chicks (Wijerathne *et al.*, 2023).

The habitats of the Sri Lanka Grey Hornbill primarily encompass the rainforests, evergreen forests, and deciduous areas of Sri Lanka. These forests provide food sources and suitable nesting sites for the hornbills, allowing them to survive in their natural environment. Previous studies have found several nests in natural forests in Anuradhapura District, and have highlighted key tree species such as *Manilkara hexandra*, *Madhuca longifolia*, *Azadirachta indica*, *Melia azedarach* and *Mitragyna parvifolia* to be preferred hornbill nest trees (Wijerathne and Wickramasinghe, 2019). These trees are probably used due to their large girths (Wijerathne and Wickramasinghe, 2019). However, like many wildlife species, the hornbills face threats from deforestation, habitat loss, and unavailability of preferred food (Wickramasinghe and Wijerathne, 2022). Hence, introducing artificial nests would be one of the solutions for hornbills to overcome the problem of lack of large trees with suitable cavities. Here, we report our observations of an artificial nest within a suburban home garden in North Central Province in Sri Lanka, to determine the quality of this nest based on the survival and fledging of their offspring.

This nest was found in a home garden 1.5 km from Anuradhapura, North Central Province of Sri Lanka (Fig.1). The nest was around 1.8 meters above ground within an aluminum pot atop a mango tree. This pot was previously used by the homeowners to grow an ornamental plant. The pot was 40 cm in diameter at its widest (Fig. 2) and its opening was 13 cm wide.

Observations of the nest were for 5 months from March to July 2023 for the duration of

Fig. 2. The nest of a Sri Lanka Grey Hornbill made in a pot in a home garden.

the nesting period until chicks fledged. Observations were taken in 15-minute intervals from 0600 to 1800 hr on two random days in a week for a total of approximately 400 hours over the nesting period. Focal sampling (Altmann, 1974) was used for the data collection. Feeding patterns were observed, and fecal samples were collected twice a week using a seed trap placed 1.5 m below the nest for further information of diet. The seed trap consisted of a 2 × 2 m piece of fabric. The placement of the nest had an advantage to be observed from a distance. A hide 10 m from the nest tree was used for observations without disturbing the behavior of the nesting hornbills.

Both the male and female had searched for nesting sites in early March. The female visited this pot a few times, examined it and then started cleaning the cavity. Throughout this time, the male fed the female. The female laid a clutch of eggs in the last week of March 2023. The imprisoned female was frequently fed by the male during this time. The feeding frequency was 3.5 ± 0.6 (SD) times per hour. The incubation period lasted for approximately 30 days, and during this time, the male fed the female various kinds of fruits, insects, and occasionally snails and other food sources such as rice and string hoppers (local noodles). During the hours of 0600 hr to 1000 hr, the female was mostly fed fruits and insects. But by 1100 hr the food delivered appeared to completely shift to a mostly insect diet, with occasional fruits, snails and other foods like cooked rice and string hoppers being brought to feed the female (Fig. 3). Snail shells, bone-like particles and oil lamp wicks were also observed among the feces collected from the seed traps (Fig. 4).

By the end of April, the chicks had hatched, as noticed from the frequent chirping noises. During the start of May, the frequency of visits by the male increased compared to April (Fig. 5). The feed that was bought and the feeding frequency after the hatching of eggs was irregular throughout the day compared to during incubation but still consisted of the same items. The feed mainly consisted of insects with some fruits and nuts with an occasional snail shell.

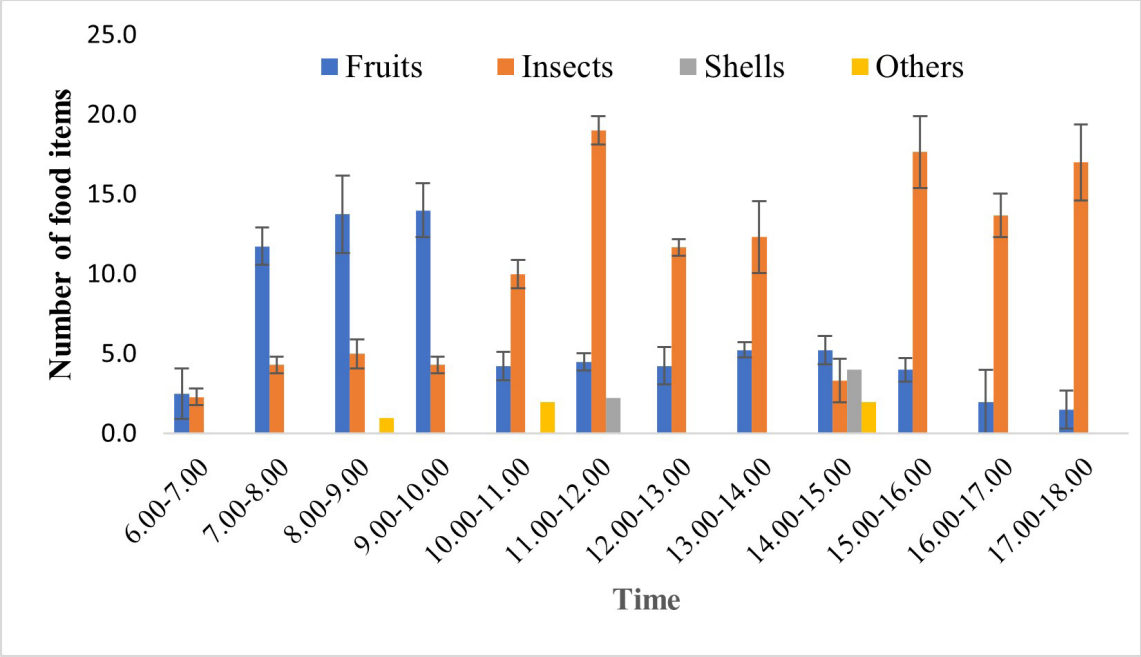

Fig. 3. Feeding frequency during incubation (error bars indicate standard deviation).

During this time, the male still brought rice and oil lamp wicks, but only one lizard was recorded throughout May (Fig. 4 and Fig. 5). By this time, the chicks had sufficiently grown to the point the nest was somewhat cramped.

By June 12th, the female broke through the nest seal with new, slightly darker feathers after moulting. During this time, it was observed that there were three chicks within the nest. The feeding frequency increased yet again. It was the highest ever recorded throughout the study (Fig. 6). During this time, roughly 91% of the diet consisted of insects with fruits and small reptiles. There were also occasions of rice and oil lamp wicks (Fig. 5). By the 20th of June, the female started feeding the chicks as well. We monitored the chicks during this time. By the end of June, the three chicks had well-developed plumage, but only one had developed its tail feathers (Fig. 7).

Fig. 4. Male carrying a snail shell (left), lizard being brought by the male (middle), Male carrying an oil lamp wick (right).

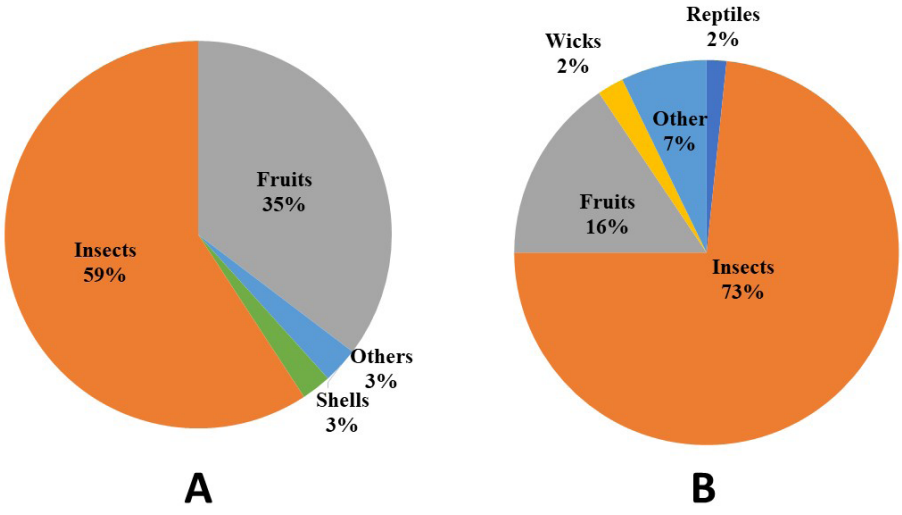

Fig. 5. Composition of diet of the Sri Lanka Grey Hornbill (A) During Incubation; (B) After the female left the nest.

On the first of July, the largest of the three chicks fledged the nest accompanied by both parents. The body size of the fledged chick was smaller than the adult with a developed plumage and somewhat developed tail feathers. The male returned occasionally to feed the other two chicks, but an overall number of visits to the nest was lower than before the first chick fledged. The second chick fledged on the 6th of July, while the third and last chick

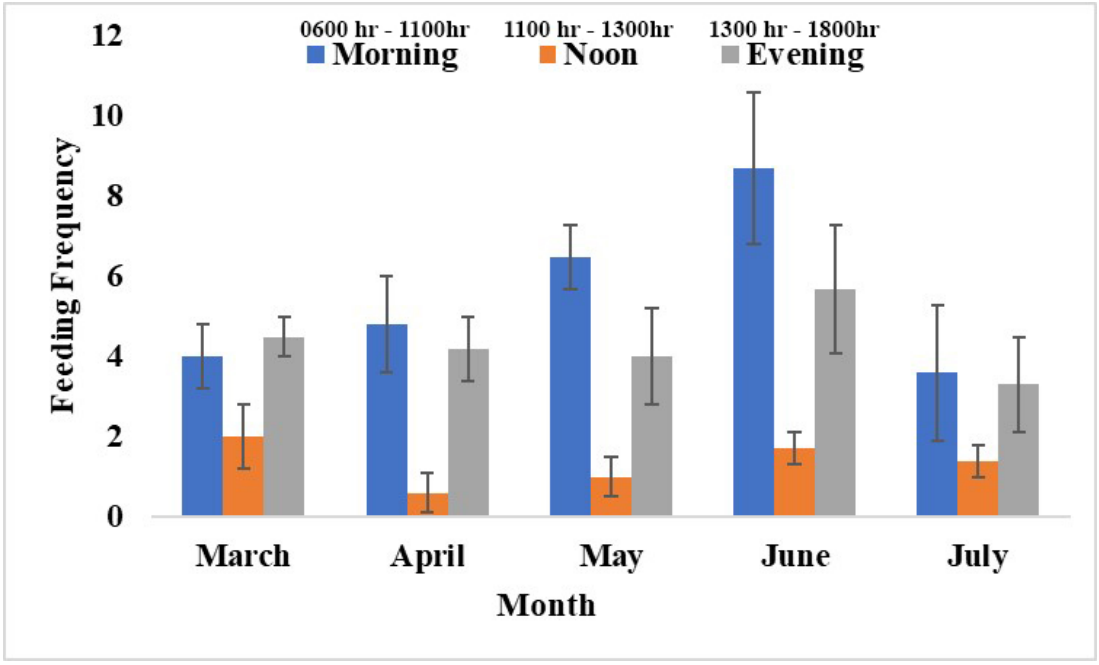

Fig. 6. Feeding frequency by the nesting Sri Lanka Grey Hornbill in different months throughout the nesting season.

Fig. 7. Most and least developed chicks beside each other (left). All three chicks with least developed in front and most developed at the back. Developed tail feathers seen on the largest chick (right).

fledged on the 9th of July. Overall, the feeding frequency during this time was at an all-time low (Fig. 6). However, there was an increase in fruits during this phase compared to the rest of the weeks. The nesting site was monitored for another two weeks, and the parents along with the three offspring were seen to be in good health as they passed by the old nest from time to time.

Discussion

In summary, this Sri Lanka Grey Hornbill nest took 110 days to complete incubation, hatching and fledging. This finding is like previous studies conducted in natural forest ecosystems by Wijerathne and Wickramasinghe (2018). The present study allows us to speculate that the diet composition in urban areas may differ from that of hornbills nesting in natural forests. In the wild, the majority of the diet consisted of multiple species of figs and fewer insects (Wijerathne *et al.*, 2023). But in the current study, this bird mainly fed on insects, which suggests a scarcity of figs in this urban setting. We also recorded the bird consuming a number of oil lamp wicks. Currently we do not have any reasoning behind this feeding behaviour. The need for required oils was also recorded in a study based on food availability and food selectivity of Sri Lanka Grey Hornbill conducted by Wijerathne *et al.* (2023). The maximum number of offspring found in natural nests so far was two, as found by Wijerathne and Wickramasinghe (2019), but in this nest, three male chicks successfully fledged. This may be due to its larger size of the pot compared to natural tree cavities, but further studies are needed.

References

Altmann J. 1974. Observational studies of behaviour: sampling methods. *Behaviour*, 49: 227–266.

Kemp AC. 1995. *The hornbills*. Oxford: Oxford University Press.

Kotagama SW, Kalathota C, *et al.*, 2011. Distributional Status of Hornbills in Sri Lanka, 1993-

2009. *Raffles Bulletin of Zoology Supplement* 24: 77–83.

Legge WV, 1880. A history of the birds of Ceylon. Republished 1993 by Tisara Prakasakayo, Dehiwala, Colombo. https://doi.org/10.5962/bhl.title.127685

Wickramasinghe S and Wijerathne I. 2022. A brief overview of the Malabar Pied Hornbill and Sri Lanka Grey Hornbill species in the Western Ghats and Sri Lanka. *WILDLANKA*, 10: 179–189.

Wickramasinghe S, Panduwawala P, *et al.*, 2018. Distribution and habitat ecology of Sri Lanka Grey Hornbill (*Ocycerous gingalensis*) in the Anuradhapura district, North Central province, Sri Lanka. *WILDLANKA*, 6: 1–7.

Wijerathne I, Panduwawala P, *et al.*, 2023. Food availability and food selectivity of Sri Lanka Grey Hornbill (*Ocyceros gingalensis*) Shaw, 1811 in Mihintale Sanctuary,Sri Lanka. *Journal of Threatened Taxa*, 15:1, DOI: https://doi.org/10.11609/jott.7249.15.1.22399-22409

Wijerathne I and Wickramasinghe S. 2019. Nest cavity characteristics and nesting success of Sri Lanka Grey Hornbill (*Ocycerous gingalensis*) in Mihintale Sanctuary, Sri Lanka. *International Journal of Environment and Biodiversity*, 10: 93 – 98

Wijerathne I and Wickramasinghe S. 2018. Behavioral pattern of endemic Sri Lanka Grey Hornbill (*Ocyceros gingalensis*) within the breeding and nonbreeding seasons. International Journal of Biodiversity, 2018: 1–7. https://doi.org/10.1155/2018/9509785

Damindu J.C. Wijewardana

Iresha I. Wijerathne

Sriyani Wickramasinghe

Spatial characteristics of the Black Hornbill *Anthracoceros malayanus* nests in disturbed forests of Kapuas Hulu Regency, West Kalimantan, Indonesia

Riki Rahmansyah[1,*], Firman H. Kurniawan[1,2], Mikael Repormanto[1,3], Nurul L. Winarni[4], and Yokyok Hadiprakarsa[1]

[1] *Rekam Nusantara Foundation, Rangkong Indonesia, Bogor, West Java, Indonesia*

[2] *Natural Resources and Environmental Management, IPB University, Bogor 16680, Jawa Barat, Indonesia*

[3] *Department Biology, Faculty of Mathematics and Natural Science, Tanjungpura University, Pontianak, Kalimantan Barat, Indonesia*

[4] *Research Center for Climate Change, Universitas Indonesia, Depok 16424, West Java, Indonesia*

***Corresponding author:** Riki Rahmansyah (riki@rangkong.or.id)*

Abstract

The Black Hornbill Anthracoceros malayanus *is known to prefer lowland forest habitats and also persists in disturbed forests. However, the extent of its use in disturbed areas remains poorly understood. This study investigated the Black Hornbill's habitat preference in Kapuas Hulu Regency, West Kalimantan, Indonesia. We used spatial analysis to explore the spatial characteristics of 15 active nests. The nests were found in lowland areas (<500 m asl) and mainly in dry-mixed farmlands (33%) and secondary dryland forests (27%). The remaining nests were in the secondary swamp (20%), shrub forests (13%), and dryland agriculture (7%). Most of the nest trees were in* Shorea *spp. (Family Dipterocarpaceae) with the diameter at breast height (DBH) ranging between 0.35 – 1.20 m and a height range of 20 – 50 m. Around 67% of the nests were situated along the perimeter of shifting cultivation fields or near trails or settlements. One nest was about 100 m from the closest trails, while the closest nest to a settlement was about 500 m away. The spatial analyses also revealed the proximity of the nests to potential anthropogenic disturbance sources such as road and river networks, farmland, fire hotspots, and deforested areas. The findings provide insights into the Black Hornbill's tolerance to human disturbance and habitat use. They also highlight the importance of protecting its habitat, particularly in areas with shifting cultivation fields and human settlements. This study underscores the need for further research to identify effective conservation strategies for the Black Hornbill in disturbed forests, farm edges and higher-elevation habitats.*

Keywords: Bucerotidae, conservation, nest preferences, shifting cultivation, spatial analysis

Introduction

The Black Hornbill *Anthracoceros malayanus* is a member of the Bucerotidae family and is listed as vulnerable by the IUCN *Red List of Threatened Species* (BirdLife International,

2018). In Indonesia, the Black Hornbill is a species protected by the Ministry of Environment and Forestry through Regulation P.106 of 2018 (KLHK, 2018). Its population is threatened due to land clearing and hunting, especially for consumption (BirdLife International, 2018; Kurniawan *et al.,* 2024).

Research on the breeding ecology of hornbills is crucial as it has a direct impact on increasing the population. One aspect of this research is the assessment of the nesting characteristics of the target species. Like the other hornbill species, Black Hornbill is also a secondary cavity nester (Kitamura *et al*., 2011; Poonswad, 2012). The nest cavities are usually in large, old trees, but the availability of such trees is rare (Kaur *et al*., 2020). Our survey in Kapuas Hulu recorded that the trees with such characteristics are no more than 1% of the trees in the population (Rangkong Indonesia, unpublished data). Generally, their rarity is caused by land clearing and/or natural tree falls (Kitamura *et al*., 2004; Meijaard *et al*., 2006). It is therefore necessary to study nest availability and use due to its direct influence on wildlife population sustainability (Okahisa *et al*., 2012), including that of Black Hornbill nesting and population.

So far, it is known that Black Hornbills like lowland forest habitats close to settlements and can adapt to human activities (Franco and Minggu, 2019). However, not much is known about the level of disturbance that may be tolerated by the Black Hornbill (Poonswad *et al*., 2013b). During hornbill conservation activities in Kalimantan, Rangkong Indonesia, an NGO that works on Indonesian hornbill conservation, received several reports regarding active nests of Black Hornbills. As a follow up to this work, we evaluated the spatial characteristics of nest locations and documented the disturbance levels around the nests of the Black Hornbill

Methods

Study area

This research was conducted in Kapuas Hulu Regency, Kalimantan Barat Province, Indonesia. The nest data were collected from the local community reports between November 2018 and December 2022. Kapuas Hulu Regency is in the northern part of Indonesian Borneo, adjacent to Malaysia (Fig. 1). The topography has an altitude range between 0 and 1500 m asl, and the slope ranges from 0% to 40%.

Kapuas Hulu Regency has 56.5% of its area covered by intact tropical rainforests, designated as conservation and protected areas. This regency is home to two national parks, Betung Kerihun National Park (BKNP) and Danau Sentarum National Park (DSNP), which together span 2,322,791 hectares, making it the second largest conservation area on Borneo Island. Based on our previous research (Rangkong Indonesia, 2020 unpublished data), Kapuas Hulu is an important habitat for the Helmeted Hornbill *Rhinoplax vigil* and seven other hornbill species in Kalimantan with various habitat types, including Lowland Dipterocarp, Hill Dipterocarp, Submontane Dipterocarp, Peat Swamp, Freshwater Swamp, Riparian and Heath Forest.

The public reported the nests in four villages: Karya Mandiri, Tanjung Lasa, Sungai Utik, and Pulan. The Sungai Utik and Pulan villages are adjacent to each other and situated between the two national parks, BKNP and DSNP. These two villages have relatively similar habitat types in the form of swamp *Kerangas* and lowland dipterocarp forests. On the other hand, the Karya Mandiri village is in the southern part of Kapuas Hulu, and Tanjung Lasa is in the northern part. Both have the lowland dipterocarp forest as the dominant habitat type. Tanjung

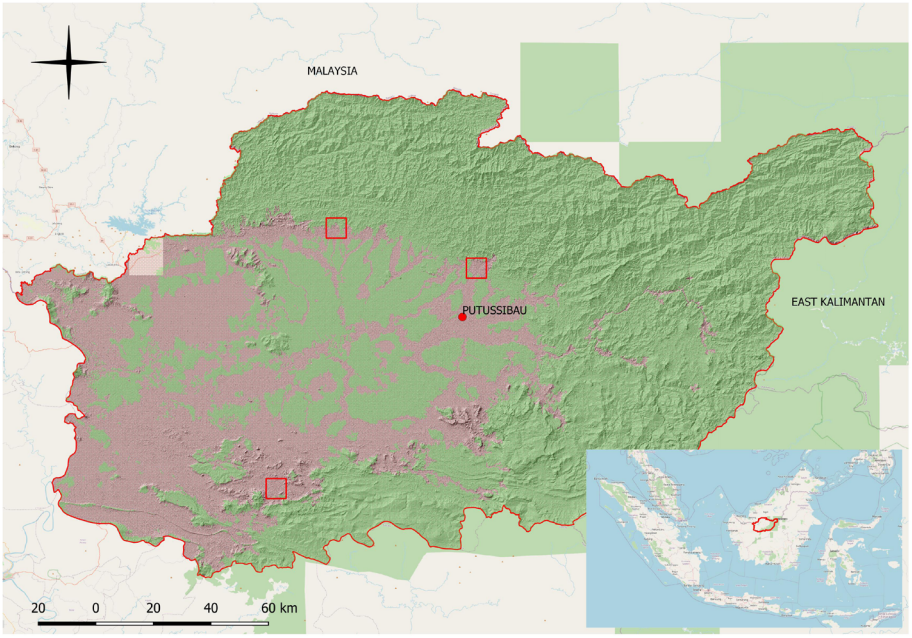

Fig. 1. The red rectangle shows the study sites in Kapuas Hulu Regency, Kalimantan Barat Province, Indonesia.

Lasa and Karya Mandiri are separate stretches of the Utik and Pulan Rivers.

Data collection and analyses

We verified all the nests reported by the local communities to ensure that the cavities had been used by the Black Hornbill for breeding. The reported nest was noted as "used" if it met one of the following criteria: (a) male was observed to feed the inmates at the nest, (b) beak of the female/chick(s) was seen at the nest cavity, (c) female/chick(s) seen coming out of the nest cavity, and/or (d) fresh droppings were observed under the nest cavity. The hornbill species was also validated based on the dropped feathers of the Black Hornbill under the nests (Fig. 2).

Previously, these nests have been inspected, tagged, identified, and observed by Reporman-to (2023). However, additional nests were found in the surrounding area, and all these nest tree characters were redescribed following Mudappa and Kannan (1997). Parameters determined

Fig. 2. Black Hornbill nest verification criteria, from left to right: The male feeds in the nest cavities; the beak of the female/chick(s) is at the nest cavities; the female/chick(s) is coming out of the nest cavities; fresh droppings were observed under the nest cavity with identified dropped feathers of the black hornbill.

were tree species identity, diameter at breast height (DBH), tree height, and nest cavity height. Instead of measuring the nest cavity dimensions, we described the shape according to Poonswad (2012) with the modification into three categories as follows: (a) Round if the width of the cavity was approximately the same as the length, (b) Oval, if the length was approximately two times the width, and (c) Slit, if the length was more than two times the width.

The nest location and disturbance level were described to determine Black Hornbill's nest site characteristics. Several parameters, including land cover, elevation, and slope, were used to describe the spatial characteristics. The topographic analysis was conducted by extracting elevation and slope data from the DEMNAS data (https://tanahair.indonesia.go.id/demnas/#/) using QGIS 3.20.1. Results from slopes analyses were categorised following Arsyad (2010) into flat (0–8%), gentle slopes (9–15%), slopes (16–25%), steep slopes (26–40%), and very steep slopes (>40%). The disturbance levels were projected by the distance to the nearest settlement, road, river, fire hotspot, paddy field, and deforestation, using Proximity Euclidean distance, which was obtained through multi-value extract (Chasar *et al.*, 2014; Hidayat and Febriani, 2021). We also included the distance to the nearest river as one of the parameters because in Kalimantan, rivers are used for transportation (Purmintasari *et al.*, 2018), and based on personal observations they are generally used as hunting routes.

All multivariate statistical analyses were performed using the 'vegan' package in RStudio statistical software, utilising the 'metaMDS' function to visualise the grouping pattern of spatial characteristics of each nesting location. Differences in disturbance levels between the studied locations measured by factors such as the distance to the nearest settlement, road, river, fire hotspot, paddy field, and areas of deforestation were visualised using non-metric multidimensional scaling (nMDS) based on Euclidean dissimilarities. The data was visualised using 'ggplot2' as a two-dimensional ordination and ellipses, which showed 95% confidence intervals based on standard error. Data validation was conducted using a one-way Analysis of similarity (Anosim) test with 95% significance to determine whether there are significant differences in the identified threat data, utilising the 'Anosim' function of the 'vegan' package.

Results

Nest characteristics

A total of 30 nests had been reported by the local community from 4 settlements. However, only 15 nests were verified as being used by Black Hornbills. Most of the active Black Hornbill nests were in Sungai Utik (7), followed by Pulan (6), and Karya Mandiri and Tanjung Lasa with one nest each. Meanwhile, the remaining 15 nests were identified as being used by other hornbill species, namely Wreathed Hornbill *Rhyticeros undulatus*, Rhinoceros Hornbill *Buceros rhinoceros*, and Bushy-crested Hornbill *Anorrhinus galeritus*, and/or broken nests that were not used by hornbills anymore. Most of the nest trees were identified as *Shorea* spp. of the Dipterocarpaceae Family. The average ± SE of the DBH of the nest trees were 74.0 ± 7.1 cm (range: 35.7–120 cm), and the tree height was 29.7 ± 3.0 m (range: 20–50 m). The height average of nest cavities was 6.4 ± 1.4 m, with the lowest height being 2 m above the ground. Ten nest cavity openings were slits, while three were round, and two were oval (Table 1, Fig. 3).

The nest spatial characteristics

Spatially, all nest positions were in lowland habitat < 500 m asl (Fig. 4a). Based on the to-

Fig. 3. The nest hole shape recorded in this study. Above, from left to right: S001, S002, S003, S004, S005. Center from left to right: S006, S007, S008, S009, S010. Below from left to right: S011, S012, S013, S014, S015.

pography, most nests were situated on a gentle slope (9–15%), and only a single nest was on a steep slope (26–40%) (Fig. 4b). None of the nests were in primary forests. Based on the 2016 land cover data (KLHK, 2020), seven nests were in secondary forest areas, while eight were found in non-forest areas. Of the seven nests, four were in the secondary dryland forest type,

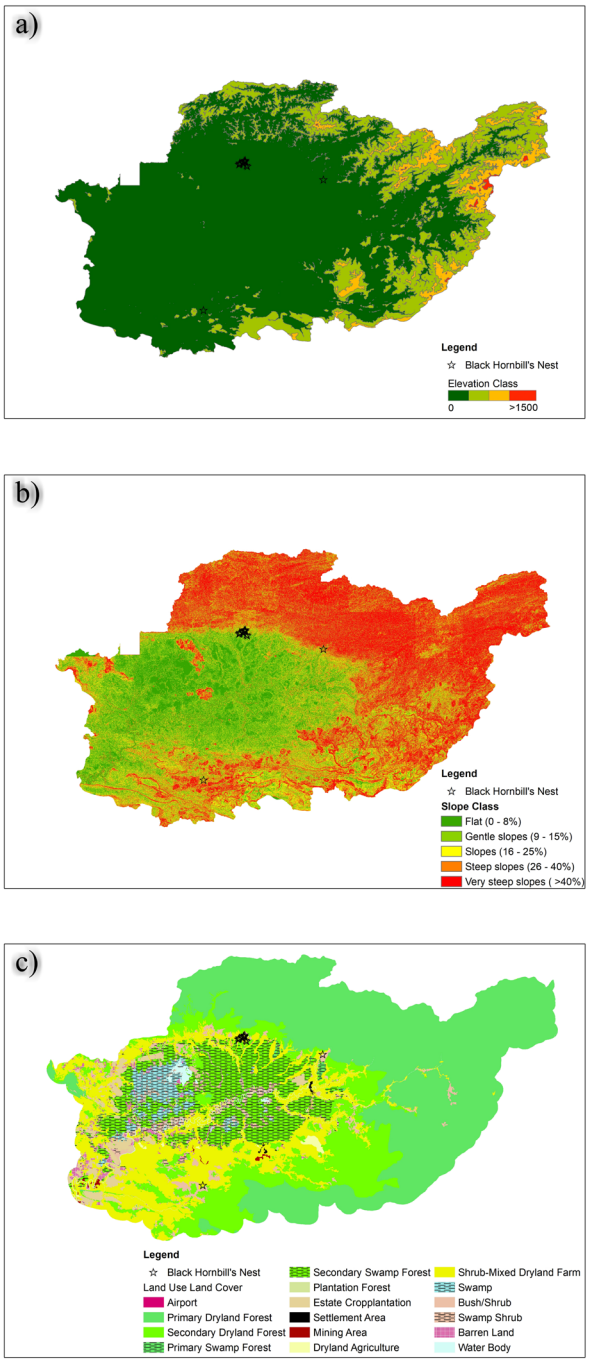

Fig. 4. The spatial location of Black Hornbill nests based on: a) topography, b) slope, and c) land cover.

and three nests were in the secondary swamp forests. The eight nests in the non-forest area were in the shrubs (2), shrub-mixed dryland farm (5), and dryland agriculture (1). Based on the spatial location of the Pulan settlement, it is closest to patches of secondary swamp forest (170 m) and secondary dryland forest (150 m), while the other three settlements are farther from forest patches and closer to dry agricultural land (Fig. 4c).

Disturbances tolerated by Black Hornbill

Although we did not conduct preference analysis, considering that the sample originated from opportunistic data, we observed disturbance levels tolerated by the Black Hornbill based on the distance of the nest from the nearest disturbance centre. The analysis revealed that the average distance (± SE) between the nests to the nearest road was 1,433 (± 518.1) m (range: 109–8,141 m), nearest settlement was 1,419.3 (± 226.8) m (range: 525–3,363 m), paddy-field was 53.7 (± 23.4) m (range: 0–277 m), river was 859.5 (± 513.5) m (range: 47–514 m), fire hotspot was 1425.3 (± 163.3) m (rang: 489–2633 m), and to the deforested area was 1,812.6 (± 411.6) m (range: 488–6,086 m) (Fig. 5). The Euclidean analysis also found that four active Black Hornbill nests (S002, S008, S009, and S014) were at zero metre distance from paddy fields.

Based on the nMDS analysis, two groups with similar disturbance sources were identified: Group 1 (Pulan) and Group 2 (Sungai Utik, Karya Mandiri), while Tanjung Lasa (S008) was separate on its own (see Fig. 6). From this grouping, the stress value obtained was 10%, indicating that the model performance was quite good, and the Anosim R^2 value obtained was 0.74. Subsequent model testing using one-way ANOSIM revealed significant differences in threat data between nests in Sungai Utik and Pulan ($p < 0.001$).

Discussion

The spatial analysis supports the statement of Poonswad *et al.* (2013b) that the Black Hornbill species were generally found below 200 m above sea level and are rarely observed in areas

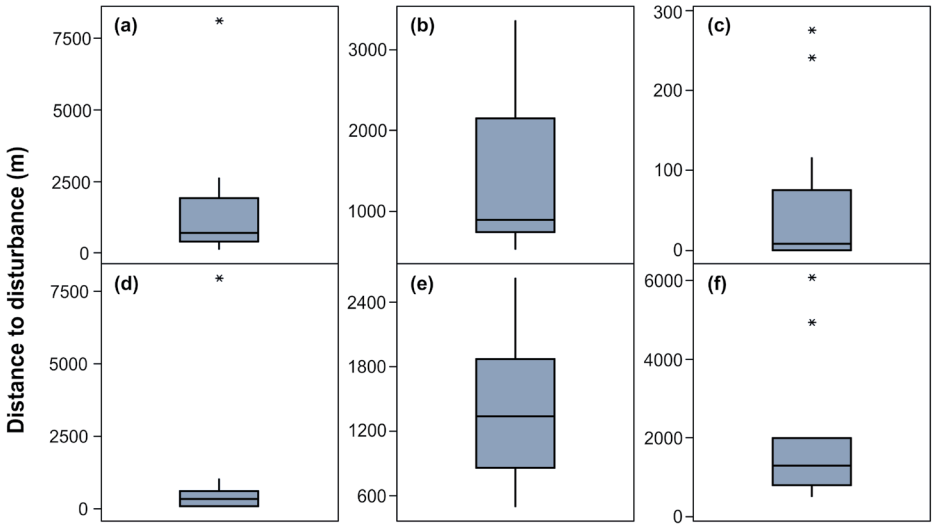

Fig. 5. Distance between Black Hornbill nests with several disturbance level, i.e., road (a), settlement (b), paddy-field (c), river (d), fire hotspot (e), and deforestation (f).

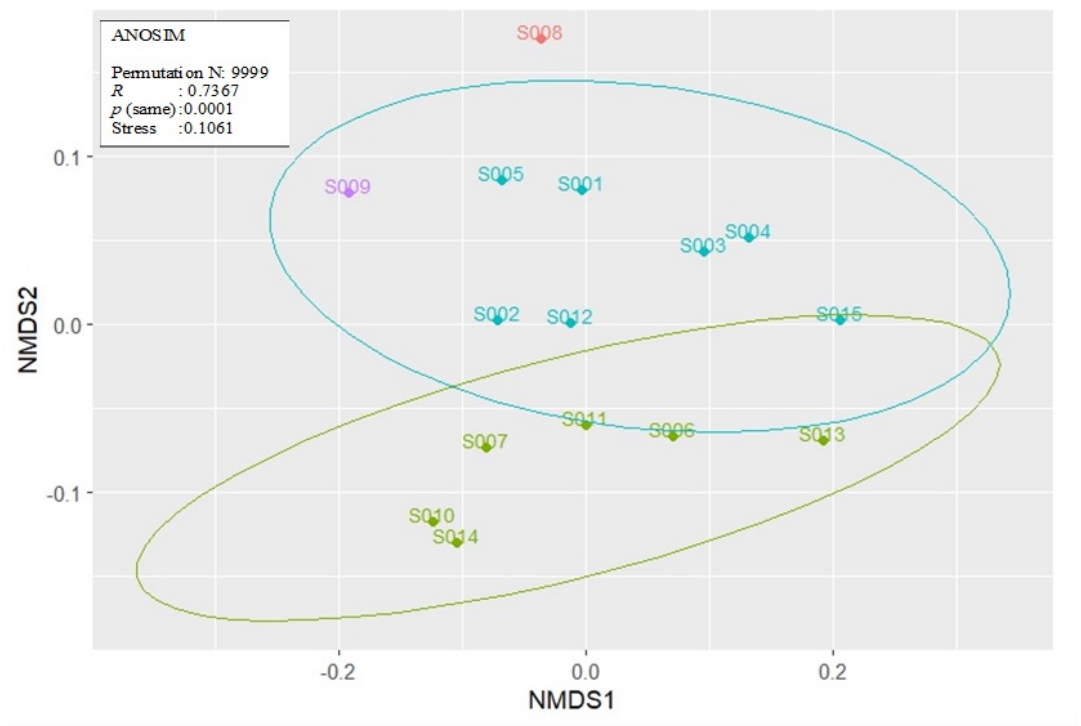

Fig. 6. Clustering patterns of hornbill nests based on disturbance levels Using NMDS.

>600 m above sea level. In the context of nest tree characteristics and nest cavity, this study also corroborates the assertion by Kaur *et al.* (2020) that hornbills exhibit specific preferences for selecting large-sized nest trees with a diameter at breast height (DBH) exceeding 40 cm, typically found within the Dipterocarpaceae family in lowland forests (Poonswad *et al.*, 2013a; Santhoshkumar and Balasubarmanian, 2010).

With additional nest data, this research reaffirms Repormanto's (2023) findings. It also supports Datta and Rawat's (2004) statement that the dimensions of the cavity are more crucial for hornbill nest suitability than the characteristics of the nesting habitat, given that nests were found in non-forest areas.

Usually, potential nest cavities used by Asian hornbills are typically situated at considerable heights, averaging over 10 metres (Rahayuningsih *et al.*, 2017; Kaur *et al.*, 2020). The selection of these nest sites is associated with enhanced safety levels when nests are positioned higher, thereby minimising disturbances from other animals or humans (Ismail *et al.*, 2015). Recently, the nest height of a Narcondam Hornbill (*Rhyticeros narcondami*) was recorded at 4 m above ground (Naniwadekar *et al.*, 2020). Our two-metre nest above the ground S014 may be Indonesia's lowest recorded natural hornbill nest. The low height of the hornbill nest was probably due to limited trees with cavities available, which forces them to nest at lower heights (Naniwadekar *et al.*, 2014). Another unique finding was that the nests were situated in non-forested areas. In general, hornbills are known to inhabit primary forests such as those found in Java, Kalimantan, Sulawesi, India, and Thailand (Kinnaird and O'Brien, 1999; Klop *et al.*, 2000; Poonswad, 2012; Rahayuningsih *et al.*, 2015), including the Black Hornbill in Sumatra (Hadiprakarsa *et al.*, 2007). The decrease in the availability of large trees results from logging, leading to a decline in tree population in the habitat, particularly at the study site where we found that trees from the Dipterocarpaceae Family are often logged for trade and as building materials by the local community.

The shape of the cavity entrance used by the Black Hornbill was mostly in the form of a slit, while a few were round or oval. The choice for a particular entrance shape could be specific to hornbill species (Poonswad, 2012). Meanwhile, the entrance shape for large hornbills, such as the Rhinoceros and Wreathed Hornbills, tends to be slit-shaped (Repormanto 2023). According to Utoyo *et al.* (2017), the nest entrances for the Helmeted and Wreathed Hornbills are large in dimension and typically round or oval. Most of the nest trees were identified as *Shorea* spp. in the Family Dipterocarpaceae, while a single nest was in a Lauraceae tree.

These unique findings can be caused by the high adaptability of the genus *Anthracoceros* to the limited resources surrounding their habitats (Poonswad *et al.*, 2013a). Although the information for the Black Hornbill is limited (Poonswad *et al.*, 2013a), a closely related species, the Oriental Pied-Hornbill *Anthracoceros albirostris*, has often been noted to adapt well to limitations in supporting resources and habitat disturbances (Datta and Rawat, 2004; Yusran *et al.*, 2023). An extreme case is the report of Oriental Pied-Hornbills in Malaysia that used a jar as a nest and as a response to the limited natural nest availability (Ismail *et al.*, 2015).

Small-sized hornbills are known to have better adaptability compared to larger hornbill species (Gopalan, 2021). In response to environmental changes, the genus *Anthracoceros*, including the Black Hornbill, prefers to change the com-

A village close to a Lowland Dipterocarp Forest.

position of their food rather than emigrating like the larger hornbills such as the Rhinoceros, Wreathed, and Helmeted Hornbills (Poonswad *et al.*, 2013a). It is not surprising that several studies have recorded the presence of the Black Hornbill in habitats such as tidal swamp forests, extending to secondary and nearby forest edges (Akbar *et al.*, 2020; Franco and Minggu, 2019). Some studies have recorded the presence of the Black Hornbill around oil palm plantations on the same island of Kalimantan (Akbar *et al.*, 2020; Nur *et al.*, 2013). This study also adds to the growing knowledge of the adaptability of the Black Hornbill, showing it can live in non-forest areas or predominantly human-use areas.

Based on the grouping of characteristics, it is evident that Group 1 (Pulan) has nests that tend to be close to four sources of disturbance: roads, settlements, paddy fields, and rivers. In contrast, Group 2 (Sungai Utik) included four nests (S002, S004, S012, and S015) with characteristics like those in Pulan. The other two groups, Karya Mandiri (S008) and Tanjung Lasa (S009), are closer to rice fields and tend to be farther from the other four sources of disturbance. In Pulan, the settlements are located near forest patches, and land cover for farming is concentrated in one area. In contrast, settlements are far from forest patches in the other three locations, and paddy fields are not concentrated in one area. When considering the distance of the settlements to the forest patch, Pulan is the closest at 150 m, followed by Sungai Utik at 1,160 m, Tanjung Lasa at 1,104 m, and the farthest being Karya Mandiri at 4,336 m.

We also noted that all nests were at least 400 m away from disturbances such as fire hotspots

caused by fresh land clearing for paddy fields. It has long been recognised that the traditional farming culture in Kalimantan remains deeply rooted in ancestral traditions, particularly in shifting cultivation systems (Kwirinus and Yuniarto, 2023). This agricultural practice continues to involve land clearing through burning as part of its sequence. This system ensures local food security, and also plays a crucial role in preserving the local wisdom of the Kalimantan people (Kwirinus and Yuniarto, 2023). However, such activities will likely affect the existence of Black Hornbill nests. We recommend the establishment of regulations for the protection of nesting areas at the local level based on customary laws. This approach can leverage the historical social capital, particularly the local community's (notably the Dayak people's) respect for hornbills (Bennett *et al.*, 1997; Furness, 1902).

Limitations

However, it is important to note that the data is opportunistic, so it cannot be concluded that the measured spatial or physical characteristics reflect the preferences of Black Hornbills. To determine preferences, a more structured survey design with a more representative sample size and considering all the existing habitat types (Lopez *et al.*, 2023) will have to be carried out. The reports provided by the community were certainly based on areas they usually explore. This study has not covered areas not commonly visited by the community and natural forest areas.

The data collected by the Batu Lintang community is an outcome of Community-Based Monitoring (CBM) initiated by Rangkong Indonesia, considering the community's involvement in gathering scientific data (Gofman, 2010). The challenges in implementing CBM include limited community participation, constrained capacity-building training time, financial limitations, inconsistent data collection using technology, weak integrity in supervision, social conflicts among communities, and restricted communication among local staff, all of which pose challenges in monitoring.

Although this study found that the Black Hornbill can live around human communities with non-forest cover types such as shrubs, shrub-mixed dryland farms, and dryland agriculture, further investigation is necessary. This is a limitation of this study, considering that the secondary land cover data used has a broad scope and utilises medium-resolution Landsat imagery (30 m of resolution) (KLHK, 2020). In the technical guidelines for the secondary data, slight disturbances can result in different classifications; for example, a primary forest category may become a secondary forest if a footpath is found. Validation or comparison with independent land cover analysis using more detailed imagery sources is recommended and may show different results from this study.

Conservation concerns

Despite the limitations of this study, an important finding is that most of the nests discovered are easily accessible by humans, which could threaten the Black Hornbill population there. Kurniawan *et al.* (2024) explain that the Black Hornbill is currently a target for hunting by local communities in Kapuas Hulu, the same district where the nests were found. Furthermore, research by Ismail (2015) demonstrated that despite their adaptability, human disturbances to the nests of the Oriental Pied-Hornbill in Peninsular Malaysia strongly affect breeding success. This is a concern, considering that the

Black Hornbill is more sensitive to disturbances than the closely related Oriental Pied-Hornbill. The findings provide insights into the Black Hornbill's tolerance levels and characteristics of the nest trees and highlight the importance of protecting these trees. While the Black Hornbills show some adaptability to disturbed environments, they tend to avoid fire hotspots and deforestation. The study emphasises that the data used is opportunistic, so the habitat preferences of the Black Hornbill are not yet conclusively determined. Further research is needed to understand habitat preferences in more detail, including the impact of human disturbances on breeding success, in order to identify effective conservation strategies for the Black Hornbill in disturbed forests, human use areas, and higher elevation habitats. Using high-resolution satellite imagery can provide more accurate data on land cover changes and their impact on Black Hornbill habitats.

Acknowledgments

The study was funded by the Whitley Fund for Nature and TFCA Kalimantan. The author would thank localities Antonius Paeng, Muling, Jayang, Henrik, and Kristianus Filantro for reporting the active nest that was used as study samples. Raymundus Remang for study and activity permission in Batu Lintang village. Local people Dayak Iban Menua Sungai Utik and Iban Menua Pulan for providing accommodation and consumption during the field survey in Sungai Utik and Pulan settlements.

References

Akbar PG, Taufiqurrahman I, *et al*. 2020. *Atlas burung Indonesia*. Atlas Burung Indonesia, Malang, Indonesia.

Arsyad S. 2010. *Konservasi Tanah dan Air, Edisi kedua*. IPB Press, Bogor.

Bennet EL, Nyaoi AJ, *et al*. 1997. Hornbills *Buceros* spp. and culture in Northern Borneo: can they continue to co-exist? *Biological conservation* 82(1): 41–46.

BirdLife International. 2018. *Anthracoceros malayanus: The IUCN Red List of Threatened Species 2018: e.T22682441A132372259.* Retrieved August 20, 2024. from https://www.iucnredlist.org/species/22682441/132372259.

Chasar A, Harrigan RJ, *et al*. 2014. Spatial and temporal patterns of frugivorous hornbill movements in Central Africa and their implications for rain forest conservation. *Biotropica* 46(6): 763–770. doi: 10.1111/btp.12160.

Datta A and Rawat GS. 2004. Nest-site selection and nesting success of three hornbill species in Arunachal Pradesh, north-east India: Great Hornbill *Buceros bicornis,* Wreathed Hornbill *Aceros undulatus,* and Oriental Pied Hornbill *Anthracoceros albirostris. Bird Conservation International* 14: S39–S52. doi:10.1017/S0959270905000213.

Franco FM and Minggu MJ. 2019. When the seeds sprout, the hornbills hatch: understanding the traditional ecological knowledge of the Ibans of Brunei Darussalam on hornbills. *Journal of Ethnobiology and Ethnomedicine* 15(46): 1–14.

Furness WH. 1902. *The home-life of Borneo head-hunters: its festival and folk-lore*. J. B. Lippincott Company, Philadelphia.

Gofman V. 2010. *Community based monitoring handbook: lessons from the Arctic, CAFF CBMP Report No.21*. CAFF International Secretariat, Akureyri, Iceland.

Gopalan SV. 2021. *Hornbills: the resonators of forest health.* UNDP, India.

Hadiprakarsa Y, Kinnaird MF, *et al*. 2007. Effects of forest fragmentation on hornbills across the southern Sumatran landscape. In: *The active management of hornbills and their habitats for conservation*. A. C. Kemp dan M.

I. Kemp (Eds.). The 4th International Hornbill Conference, Mabula Game Lodge: 80–91.

Hidayat RA and Febriani N. 2021. Pemodelan probabilitas sebaran habitat untuk menentukan kawasan prioritas konservasi burung rangkong gading (*Rhinoplax vigil*) di Geopark Silokek, Kabupaten Sijunjung. *Konservasi Hayati* 17(1): 35–34.

Ismail A, Rahman F, *et al*. 2015. The use of abandoned clay jars for nesting by Oriental Pied Hornbill in Sungai Panjang, Sabak Bernam. *Malayan Nature Journal* 67(1): 42–49.

Kaur R, Ramli R, *et al*. 2020. Estimating the availability of potential hornbill nest trees in a secondary forest patch in Kinabatangan, Sabah. *Forktail* 36(1): 56–62.

Kinnaird MF and O'Brien TG. 1999. Breeding ecology of the Sulawesi red-knobbed hornbill *Aceros cassidix*. *Ibis* 141(1): 60–69.

Kitamura S, Aree ST, *et al*. 2011. Characteristics of hornbill-dispersed fruits in lowland dipterocarp forests of Southern Thailand. *The Raffles Bulletin of Zoology* 24(1): 137–147.

Kitamura S, Yumoto T, *et al*. 2004. Characteristics of hornbill-dispersed fruits in a tropical seasonal forest in Thailand. *Bird Conservation International* 14(1): 81–88. doi:10.1017/S0959270905000250.

KLHK. 2018. *Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia No. P.106/MenLHK/Setjen/Kum.1/12/2018 tentang Perubahan Kedua atas Peraturan Menteri Lingkungan Hidup dan Kehutanan No. P.20/MenLHK/Setjen/Kum.1/6/2018 tentang Jenis Tumbuhan dan Satwa*. Kementerian Lingkungan Hidup dan Kehutanan, Jakarta.

KLHK. 2020. WebGIS Kementerian Lingkungan Hidup dan Kehutanan: Land Cover in 2016. Retrieved December 20, 2020, from https://geoportal.menlhk.go.id/arcgis/rest/services/KLHK/Land_Cover_in_2016/MapServer.

Klop E, Curio E, *et al*. 2000. Breeding biology, nest site characteristics, and nest spacing of the Visayan Tarictic Hornbill *Penelopides panini panini* on Panay, Philippines. *Bird Conservation International* 10(1): 17–27. doi:10.1017/S0959270900000022.

Kurniawan FH, Rahmansyah R, *et al*. 2024. Local community perceptions on the conservation of hornbill (family Bucerotidae) in West Kalimantan, Indonesia. *Biodiversitas* 25(4): 1702–1710. doi:10.13057/biodiv/d250440.

Kwirinus D and Yuniarto P. 2023. The concept of recycle farming according to Dayak Kanayatn cultural dimension. *International Journal of Ethic, Racial and Cultural Heritage* 1(1): 16–31.

Lopez D, Fonda F, *et al*. 2023. Density estimates and habitat preferences of two sympatric bird species as potential bioindicators of tropical forest alterations. *Diversity* 15(2): 208. doi:10.3390/d15020208.

Meijaard E, Sheil D, *et al*. 2006. *Hutan Pasca Pemanenan*. CIFOR, Jakarta.

Mudappa DC and Kannan R. 1997. Nest-site characteristics and nesting success of the Malabar grey hornbill in the Southern Western Ghats, India. *Wilson Bull* 109(1): 102–111.

Naniwadekar R and Datta A. 2014. Hornbill nest site characteristics and factors influencing nest tree use in Arunachal Pradesh, North-east India. *Journal of Tropical Ecology* 30(3): 293–302.

Naniwadekar R, Ghuman S, *et al*. 2020. Characteristics of Narcondam Hornbill Rhyticeros narcondami nest trees. *Hornbill Natural History and Conservation* 1(2):1–9.

Nur RF, Novarino W, *et al*. 2013. Kelimpahan dan pola distribusi burung rangkong (Bucerotidae) di kawasan PT. Kencana Sawit Indonesia (KSI), Solok Selatan, Sumatera Barat. *Jurnal Biologika* 2(1): 27–33.

Okahisa Y, Morimoto G, *et al*. 2012. The nest sites and nest characteristics of narcissus flycatcher *Ficedula narcissina*. *Ornithological Science* 11(2): 87–94. doi:10.2326/osj.11.87.

Poonswad P. 2012. *Hornbills, a Thai heritage – a world heritage*. Yin Yang Karn Phim, Bangkruay.

Poonswad P, Chimchome V, et al. 2013a. Conservation of hornbills in Thailand. In: *Conservation Biology: Voices from the Tropics (1st ed.)*. NS Sodhi, L Gibson, PH Raven (Eds.). John Wiley and Sons, Ltd: 157–166. doi:10.1002/9781118679838.ch19.

Poonswad P, Kemp A, *et al*. 2013b. *Hornbills of the world*. Draco Publishing and Distribution Pte. Ltd, Bangkok.

Purmintasari Y and Kusnoto Y. 2018. Pemukiman awal sungai Kapuas. *SOCIA: Jurnal Ilmu-Ilmu Sosial* 15(1): 71–78. doi:10.21831/socia.v15i1.22013.

Rahayuningsih M, Kartijono NE, *et al*. 2015. Spatial modeling of wreathed hornbill (*Aceros undulatus*) habitat in Mount Ungaran, Central Java. *International Journal of Environmental Science and Development* 6(6): 474–477.

Rahayuningsih M, Kartijono N, *et al*. 2017. The nest characteristics of wreathed hornbill (*Rhyticeros undulatus*) in Mount Ungaran, Central Java, Indonesia. *Biodiversitas* 18(3): 1130–1134. doi:10.13057/biodiv/d180334.

Repormanto M. 2023. *Characteristics of hornbill nests (aves: bucerotidae) in West Kalimantan, Indonesia*. B.Sc. theses submitted to Tanjungpura University, Pontianak.

Santhoshkumar E and Balasubramanian P. 2010. Breeding behavior and nest tree use by Indian grey hornbill *Ocyceros birostris* in the Eastern Ghats, India. *Forktail* 26(1): 82–85.

Utoyo L, Marthy W, *et al*. 2017. Nesting cycle and nest tree characteristics of the Helmeted Hornbill *Rhinoplax vigil*, compared to the Wreathed Hornbill *Rhyticeros undulatus*, in Sumatran lowland rainforest. *Kukila* 20: 12–22.

Yusran A, Mulyani YA, *et al*. 2023. Population status of the Oriental Pied-Hornbill in oil palm landscapes with a conserved natural habitat in Runtu Village, West Kotawaringin, Central Kalimantan. *Earth and Environ. Sci.* 1220: 012010. doi:10.1088/1755-1315/1220/1/012010.


Riki Rahmansyah


Firman H Kurniawan


Yokyok Hadiprakarsa


Mikael Repormanto


Nurul L Winarni

Table 1. Verified nest used by Black Hornbill in Kapuas Hulu Regency. FBH = the first branch height, DBH=Diameter at breast height, TH=Height of the nest tree, NH=Nest height from the ground, Shape=Slit (length>2x width), Oval (length = 2x width), Round (length=width).

No	Nest code	Local name	Scientific name	Family	FBH (m)	DBH (cm)	TH (m)	NH (m)	Shape
1	S001	Perawan	*Shorea* sp.	Dipterocarpaceae	20.3	98.2	30	15.3	Slit
2	S002	Engkabang	*Rubroshorea macrophylla*	Dipterocarpaceae	14.8	120	36.7	11.7	Slit
3	S003	Medang	N/A	Lauraceae	17.8	52.8	24.6	4.2	Slit
4	S004	Perawan Bangkit	*Shorea* sp.	Dipterocarpaceae	23.1	91.4	36.9	5.2	Slit
5	S005	Engkabang	*Rubroshorea macrophylla*	Dipterocarpaceae	17	87.6	25	3.9	Slit
6	S006	Meranti	*Shorea* sp.	Dipterocarpaceae	20	102	50	11	Slit
7	S007	Meranti	*Shorea* sp.	Dipterocarpaceae	15	43	27	7	Slit
8	S008	Engkabang, Tengkawang	*Rubroshorea macrophylla*	Dipterocarpaceae	14	70	29	2	Slit
9	S009	Kensurai (Keruing)	*Dipterocarpus* sp	Dipterocarpaceae	8	60	20	5	Rounded
10	S010	Pukul Rian	*Anisptera laevis*	Dipterocarpaceae	26	73	33	13	Oval
11	S011	Perawan Mansau	*Shorea* sp.	Dipterocarpaceae	15.9	101.9	29	4	Rounded
12	S012	Tekam	*Dipterocarpus crinitus*	Dipterocarpaceae	21.5	35.7	30	6.9	Slit
13	S013	Pukul Rian	*Anisoptera laevis*	Dipterocarpaceae	22.1	57.5	35	5.5	Oval
14	S014	Perawan Mansau	*Shorea* sp.	Dipterocarpaceae	20	69.7	30	2	Slit
15	S015	Meranti	*Shorea* sp.	Dipterocarpaceae	15	50	30	10	Rounded

Observations on Indian Grey Hornbill *Ocyceros birostris* in an Indian city reveal shifts in diet and nesting

Ajay Gadikar

13, Classic Purnima Park Colony, Opposite Radisson Hotel, Indore 452010, Madhya Pradesh, India.

***Corresponding author:** ajay.gadikar@lmsin.com*

Indian Grey Hornbill (IGH) *Ocyceros birostris* is endemic to south Asia. It is widely distributed across the plains of India. It has adapted well to human-dominated landscapes and is often seen in urban gardens, forest or horticulture nurseries, orchards, and roadside plantations, apart from the agriculture areas. IGH feeds mostly on fruits, especially figs, and the chicks are fed invertebrates to complement the carbohydrate-rich diet with proteins.

In the central Indian city of Indore, it is very commonly seen in the Residency area. This locality is the greenest part of the city, with relatively high tree cover. This area still holds the remaining big and old trees, like the *Ficus benghalensis*, *Ficus religiosa*, *Ficus racemosa* and *Azadirachta indica*. These trees also have cavities for hornbill nesting. The majority of the hornbill nests are seen in this area. The IGH breeding period coincides with the fruiting of fig trees in central India. It breeds from March to July

Image 1. Male Indian Grey Hornbill with a piece of dry chapatti (Indian Bread) at the nest.

Table 1. Summary of nest entry dates across 12 years, number of nests monitored.

Year	Earliest entry date	Latest entry date	n	March Average Temp (min)	March Average Temp (max)	March Average Humidity	Comments
2011	22-Mar	4-Apr	5	13.23	32.44	77.08	
2012	25-Mar	31-Mar	6	11.69	33.79	78.61	
2013	19-Mar	2-Apr	8	15.15	33.97	75.94	
2014	19-Mar	3-Apr	7	12.77	32.13	79.29	
2015	26-Mar	3-Apr	7	16.76	31.06	73.39	
2016	20-Mar	1-Apr	7	23.77	35.05	65.55	
2017	5-Mar	12-Mar	6	19.03	34.48	68.26	Year of early nesting
2018	18-Mar	30-Mar	7	17.74	36.90	66.96	
2019	6-Mar	18-Mar	8	15.69	35.06	68.97	Year of early nesting
2020	No Data	No Data		15.37	31.44	83.37	
2021	7-Mar	14-Mar	7	24.19	34.81	87.61	Year of early nesting
2022	13-Mar	19-Mar	5	16.39	34.76	78.33	

(Ali and Ripley, 1983). Their breeding cycle was reported between 20th March and 22nd June in a study of six nest sites in Nagpur, Maharashtra (Kasambe *et al.*, 2011). As per another study in Eastern Ghats (Santhoshkumar and Balasubramanian, 2015) the nesting started early in March and ended in late June. The nesting period averaged 87 days, with the female sealed in the nest cavity. Here, I report aspects of IGH diet and nesting from more than a decade of monitoring IGH in an urban environment.

Since 2010, I have monitored an average of eight nests (range: 7 – 9) during their breeding

Image 2. Indian Grey Hornbill feeding on Gathia (savoury snack made from chickpea flour) with House Crow Corvus splendens

Image 3. The male feeding the nest inmates in the hole in a concrete wall.

Image 4. The male feeding the female at another nest site in a concrete wall.

season in the Residency area. The Residency area includes the residences of the Senior Government officers posted in the Indore district, Residency Kothi, Horticulture Nursery, Biodiversity Nursery, Forest Department Nursery, Agriculture college and its premises and Indore Zoo of Indore city. Only one of the nests was outside the Residency area. It was 1.2 km from

Image 5. The nest entrance is sealed properly just like in naturally formed nest-cavities.

the Residency area. I used Binoculars (Nikon Monarch 8 × 42 and Olympus 10×50) and a Nikon DSLR D90 Camera with a zoom lens for observing and taking records at the nest. As most of the nests were in close proximity, one observer was able to keep a watch of two to three nests at the same time. In 2013, I installed CCTV cameras to document the whole nesting cycle at one nest.

In the recordings at the nest, for the first time I documented the male IGH providing pieces of dry chapattis (Indian Bread) and biscuits regularly to the chicks (Image 1). Other than this, the Indian Grey Hornbill were also seen feeding on poha (a savoury dish made from puffed rice) (Gadikar, 2017a and 2017b) and gathia (a savoury snack made from chickpea flour) (Image 2). In the urban setting, thus I documented IGH having a changed diet.

In 2015, an IGH pair used a hole (cavity) of a concrete wall of a multi-storied residential building for nesting. Till then, it was known that the hornbill makes nests in cavities inside the tree trunk or artificial nest boxes. IGH has successfully nested in this artificial cavity in an apartment for three consecutive years (Image 3). Similarly, in 2018, an instance of successful nesting in an apartment cavity has been documented elsewhere in the city as well (Image 4). However, in this case, the cavity was only used for one year. These are examples of hornbills using modified structures in cities for nesting. The hornbills seal the opening of the concrete wall in the same way as they seal a naturally formed cavity entry (Image 5). In all three attempts, the nesting was successful, with two chicks fledging each year from it, almost the same success rate as compared to the other nesting attempts. This also points to a fact that nesting cavities may be limited in availability in urban areas like Indore.

The observations on female first entry dates in the nesting cavity at the start of the breeding cycle also yield some insights into shifting nesting timings. Table 1 displays the data of female earliest and latest entry dates in the nest cavity over the years. The data observed on the

female entry dates at the nest sites indicates earlier nesting in some years.

IGH are typically known to nest from the end of March onwards. For the first seven years of monitoring, I documented that IGH were mostly beginning to nest in the first week of April and occasionally in the last week of March. But in years 2017, 2019 and 2021, they began nesting at least two weeks before the usual nesting period. The reasons for early nesting in these years are not known. However, similar shifts in hornbill nesting have been reported from Eastern Himalaya as well (Datta, 2022). The temperatures of March (high and low) and the humidity do not show any clear association for their early nesting. Within these three years of early nesting, the nesting success was slightly higher in two of the three years, i.e., in 2017 and 2019. The breeding success was 12-15% higher for these two years, It is important that long-term monitoring of hornbill breeding should be initiated and determinants of variation in nesting and its impact on nesting success be determined.

There is very limited information on hornbills in urban environments. This note demonstrates that the Indian Grey Hornbill forages on non-natural food items and nests in artificial structures in a tier-two city in India (Gadikar, 2017). The long-term study also demonstrates variations in their nesting cycle. Future studies should aim to determine the drivers of these variations in nesting and their impact on hornbill populations.

Acknowledgements

I want to thank the then Chief Conservator of Forests (CCF) of Indore and Retd. Dr. P.C. Dube for supporting the study. Thanks are due to APCCF Dr B.S. Annigeri for his wholehearted support during the study. I thank Dr. Aparajita Datta and Dr. Rohit Naniwadekar for helping me analyse the data. Thanks to Mr Pravar Morya, Mr Vasudev Sharma, Neel Gadikar, Sarika Kaushal Gadikar and the forest nursery staff for their help during the fieldwork. I would also like to thank the late Mr. P.M. Laad, Mr. Raju Kasambe and Mr. Anil Pimpalpure for their input during the study. A special thanks to Dr. Satish Pande for his continued motivation.

References

Ali S. and Ripley SD. 1987. *Compact handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka*. 2nd ed. Delhi: Oxford University Press. Pp. i–xlii, 1 l., 1–737, 52 ll.

Datta A. 2022. Are hornbills in danger due to extreme weather conditions? *Frontline*. https://frontline.thehindu.com/environment/hornbills-feel-the-heat-in-danger-due-to-extreme-weather-conditions/article65507078.ece.

Gadikar A. 2017a. Observations on the diet of the Indian Grey Hornbill *Ocyceros birostris* during its breeding period using video camera at Indore, Madhya Pradesh. *Ela Journal of Forestry and Wildlife* 6(3): 412–414.

Gadikar A. 2017b. Adaptations of the Indian Grey Hornbill *Ocyceros birostris* in an urban environment. *Indian BIRDS* 13(6): 167–168.

Hall EF. 1918. Notes on the nidification of the Common Grey Hornbill (*Lophoceros birostris*). *Journal of the Bombay Natural History Society* 25(3): 503–505.

Charde P, Kasambe R, and Tarar JL. 2011. Breeding behaviour of Indian Grey Hornbill *Ocyceros birostris* in Central India. *The Raffles Bulletin of Zoology*. Supplement No. 24: 59–64.

Nagare A. 2014. Indian Grey Horn Bill [sic] *Ocyceros birostris* successfully nesting in an artificial nest box and fostering an orphaned fledgling.

Ela Journal 3(4): 8–10.

Newnham A. 1911. Hornbills devouring young Paroquets. *Journal of the Bombay Natural History Society* 21(1): 263–264.

Patil N, Chaturvedi N, and Hegde V. 1997. Food of Common Grey Hornbill *Tockus birostris* (Scopoli). *Journal of the Bombay Natural History Society* 94(2): 408–411.

Santhoshkumar E and Balasubramanian P. 2010. Breeding behaviour and nest tree use by Indian Grey Hornbill *Ocyceros birostris* in the Eastern Ghats, India. *Forktail* 26: 82–85.

Santhoshkumar E and Balasubramanian P. 2015. Food habits of Indian Grey Hornbill Ocyceros birostris in Sathyamangalam Forest Division, Eastern Ghats, India. *Journal of the Bombay Natural History Society* 111(2): 90–97.

Ajay Gadikar

A note on the death of an Indian Grey Hornbill *Ocyceros birostris* during a nesting attempt

Ajay Gadikar[1,*] and Neel Gadikar[1]

[1] *13, Classic Purnima Park Colony, Opposite Radisson Hotel, Indore 452010, Madhya Pradesh, India.*

***Corresponding author:** ajay.gadikar@lmsin.com*

Hornbill breeding is unique since the female hornbill incarcerates herself in the nest cavity during the nesting period. The female entry into and exit out of the nest cavity during the breeding period is a vulnerable period for her as she faces predation risk. The female inspects the cavity by entering and exiting multiple times. At the end of this inspection period, she starts sealing the nest opening with her excreta, and the mud which is provided by the male from outside (Kasambe, 2011). The size of the cavity entrance must be optimum for protecting the female and chicks from predation and not too small for the female or chicks to struggle while exiting. Unfortunately, human-modified habitats may provide limited nesting opportunities for these birds due to reduced tree cover, pushing them to nest in more suboptimal habitats.

The forest colony premises in Indore in the Madhya Pradesh state of India has the offices of the Chief Conservator of Forests and Divisional Forest Officer, and residential houses of

Image 1. Dead Indian Grey Hornbill female. Photograph by Neel Gadikar.

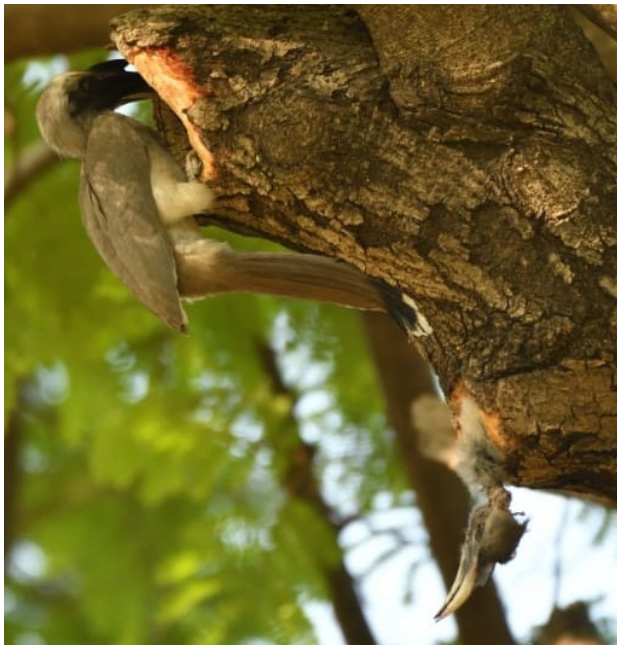

Image 2. A male Indian Grey Hornbill inspecting the cavity just above where the female had died.

the Forest Department staff, apart from a biodiversity nursery. The premises has more than 50 large trees, and many of them with multiple cavities. Many of the trees are Ficus trees that provide food to frugivorous birds. As the breeding period approaches, many pairs of hornbills are seen in the premises searching for suitable nest sites. I have been monitoring hornbill nests in this premises since 2010.

During the monitoring of the Indian Grey Hornbill (*Ocyceros birostris*) nests in the Forest Colony Premises at Indore with my son Neel, I found a female Indian Grey Hornbill that had likely died while trying to exit the nest during the early breeding phase on 21st March 2021 (Image 1).

While another cavity just above this nesting cavity has been regularly used by hornbills for nesting, this nesting cavity has never been used for breeding by the Indian Grey Hornbill over the last 5 – 6 years since I started watching this tree. However, parakeets regularly use the cavity for breeding. On closer inspection, the cavity entry appeared to be very small. We could not confirm whether the female had entered and partially sealed the nest and then struggled to exit the cavity or whether the female managed to enter but struggled to exit later due to the small cavity entrance or deep nest floor (which may not provide a suitable platform for the female to use while exiting the nest cavity). It is also likely that the female was inexperienced and likely attempting nesting for the first time. Interestingly, the next day (March 22, 2021), we found another Indian Grey Hornbill pair inspecting the cavity just two feet above where the dead female was (Image 2). This incident highlights the potential shortage of large trees with suitable cavities for nesting in urban landscapes.

References

Kasambe R. 2011. Breeding behaviour of Indian Grey Hornbill in central India. The Raffles Bulletin of Zoology 24: 59–64.

Ajay Gadikar

Neel Gadikar

The IUCN SSC HSG is hosted by:

Mandai
NATURE

nature
conservation
foundation

MABULA
GROUND HORNBILL
PROJECT